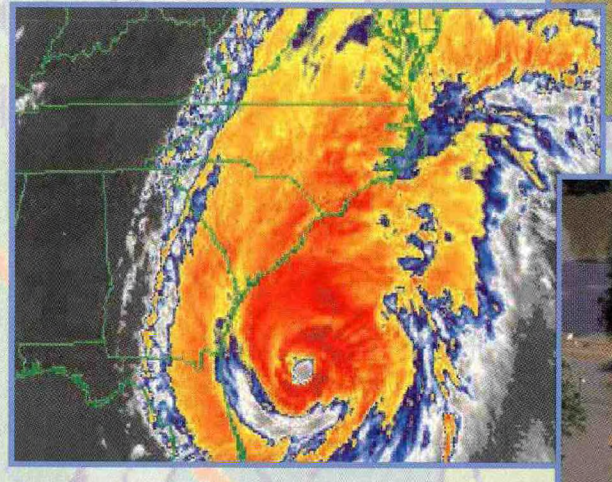
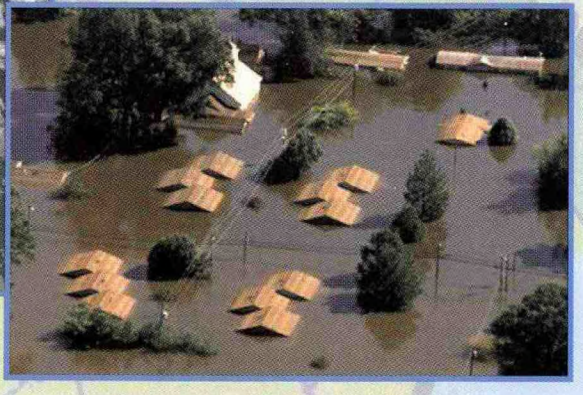
The Federal Plan for Meteorological Services and Supporting Research Fiscal Year 2001





OFCM

OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY

FCM P1-2000

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

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Special Thanks for the pictures displayed on the cover.

1) Background: Relief map background courtesy of Mr. Ray Sterner, Johns Hopkins University Applied Physics Laboratory. Rainfall analysis by NWS Southeast River Forecast Center.
2) Highway Traffic: Traffic backup on Interstate Highway I-16 in Savannah, Georgia (Savannah Morning News Photo).
3) Hurricane photo: GOES-8, 4km Infrared imagery on September 15, 1999 at 1559 UTC as Floyd approaches the South Carolina coast.
4) Aerial photo: Flooded homes in Tarboro, North Carolina (65 miles East Northeast of Raleigh) (Reuters/Joe Skipper/Archive Photos).

The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 2001

FEDERAL COORDINATOR
FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

8455 Colesville Road, Suite 1500
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PREFACE

Since 1965, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) has developed a federal plan that articulates the provision of meteorological services and supporting research by agencies of the federal government. OFCM's Federal Plan provides Congress and the Executive Branch with a comprehensive publication that documents proposed programs for Fiscal Year (FY) 2001 and reviews agency programs in FY 2000. Narratives, timelines, and schedules are current as of June 2000.

The Federal Plan consists of an Executive Summary, three sections, and an Appendix. The Executive Summary provides a high-level view of the federal resources dedicated to meteorological programs and contains information which enables it to serve as a concise, stand-alone report. The feature article (Section 1) focuses on the problem of inland flooding that resulted from Hurricane Floyd in mid-September 1999. The article is a synopsis of the meteorological conditions, the actions taken by government agencies, and the overall public response. It also highlights problem areas, such as mass evacuations of coastal flood plains and the resultant traffic congestion, associated with hurricanes that come ashore. Section 2 summarizes the resources requested in the President's FY 2001 Budget and includes a comparison of the resources that Congress appropriated for FY 2000. Section 3 contains departmental and agency narratives on meteorological services and supporting research programs. This section also includes information on programs funded by the National Science Foundation. Appendices A through D describe the OFCM's coordination, program, and planning activities; defines acronyms and abbreviations; lists previous feature articles; and summarizes the World Weather Program. The inside front cover lists the current members of the Federal and Interdepartmental Committees for Meteorological Services and Supporting Research. The inside back cover displays a schematic of OFCM's coordinating infrastructure.

As you examine this year's plan, I would like to draw your attention to the graphics and pictures included with the departmental and agency narratives. I mention this because the Internet is the source of much of the fantastic images in our publication and what you see is but a small subset of the vast amounts of meteorological information and other scientific data that is currently available. The Internet is a wealth of information and an excellent means to distribute and share information. To assist you, we've incorporated the Universal Resource Locators (URLs) to pertinent websites.

Samuel P. Williamson
Federal Coordinator for Meteorological
Services and Supporting Research

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH, FISCAL YEAR 2000

TABLE OF CONTENTS

LIST OF TABLES

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH
FISCAL YEAR 2001
EXECUTIVE SUMMARY

For Fiscal Year (FY) 2001, the President's budget requests $2.68 billion for meteorological services and supporting research. Of the total requested, $2.24 billion is designated for operations and $436 million for supporting research. Table ES-1 lists a breakout of the FY 2001 budget proposal.

As in previous years, 91 percent of the total requested funds will go to the Departments of Commerce (DOC), Defense (DOD), and Transportation (DOT). The distribution among these three departments is DOC 53.7 percent, DOD 19.8 percent, and DOT 17.4 percent. The other federal agencies will share the remaining 8.9 percent.

In comparison to the $2.5 billion appropriated in FY 2000, the FY 2001 request represents an increase of 7.2 percent. The three major departments request increases of 8.3 percent for DOC, 11.6 percent for DOD, and 5.2 percent for DOT. The DOC increase is attributable to requests for increase by NWS, NESDIS, and OAR. The DOD increases are attributable to DMSP--46.9 percent in DMSP operations and 19.6 percent in supporting research; Army systems acquisition--37.4 percent increase and an Army offset (decrease) of 18.1 percent in supporting research. DOT's increase is mainly associated with FAA supporting research request.

The budget requests for the other departments are as follows: Department of the Interior (DOI), Department of Agriculture (USDA), and Environmental Protection Agency (EPA) no change; National Aeronautics and Space Administration (NASA) a decrease of 4.0 percent; and Nuclear Regulatory Commission (NRC) a decrease of 35 percent.

Figure ES-1 depicts each agency's proportion of the requested FY 2001 federal budget for meteorological operations and supporting research. Each agency's portion of the requested funding for meteorological operations is shown in Figure ES-2. Of the $2.24 billion requested for meteorological operations, DOC, DOD, and DOT account for slightly over 99 percent of the funds. Overall, operational costs increased by 8.7 percent.

Table ES-1. Federal Budget for Meteorological Operations and Supporting Research, FY 2001 (in thousands of dollars)

Agency	Operations	% of TOTAL	Supporting Research	% of TOTAL	TOTAL	% of TOTAL
Agriculture	$12,600	0.6	$15,500	3.6	28,100	1.0
Commerce	1,349,401	60.2	92,599	21.2	1,442,000	53.7
Defense	440,610	19.7	90,505	20.8	531,115	19.8
Interior	1,100	0.0	0	0.0	1,100	0.0
Transportation	433,242	19.3	32,342	7.4	465,584	17.4
EPA	0	0.0	6,400	1.5	6,400	0.2
NASA	3,960	0.2	198,650	45.6	202,610	7.6
NRC	117	0.0	0	0.0	117	0.0
TOTAL	2,241,030	100.0	435,996	100.0	2,677,026	100.0

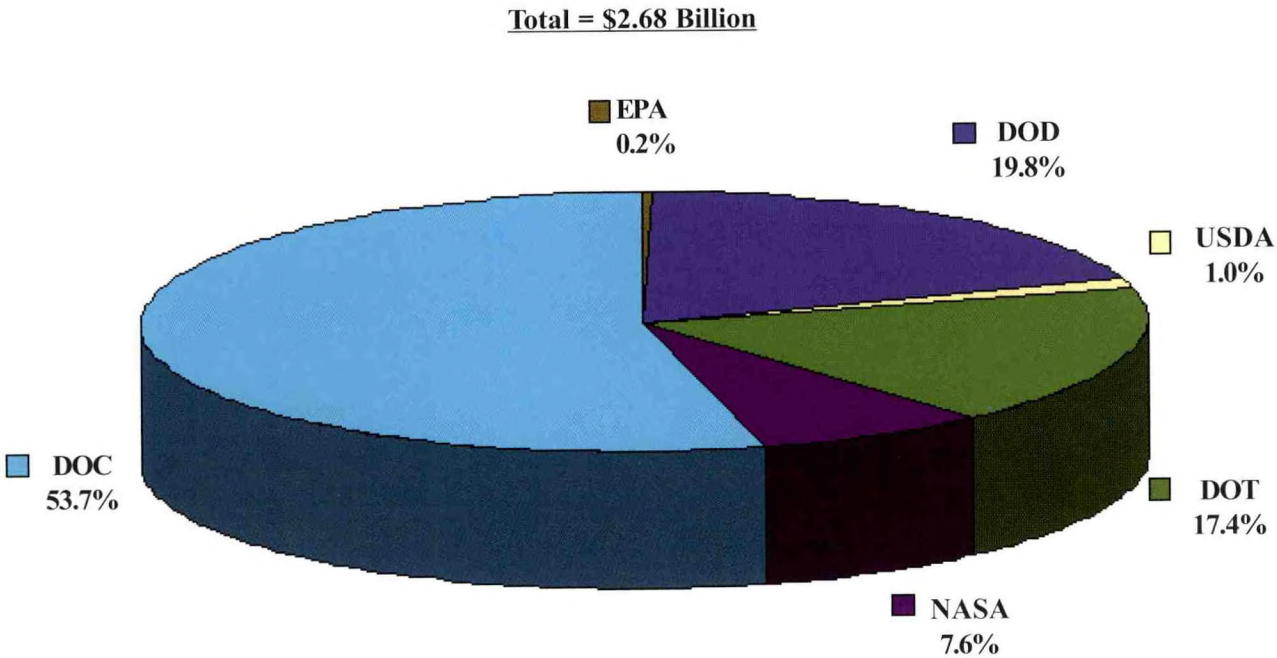

Figure ES-1. Agency Percent of Total Federal Budget for Meteorological Operations and Supporting Research, FY 2001.

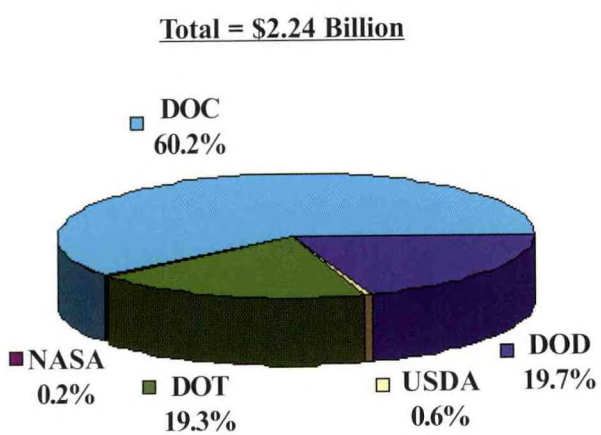

Figure ES-2. Agency Percent of Federal Budget for Meteorological Operations, FY 2001

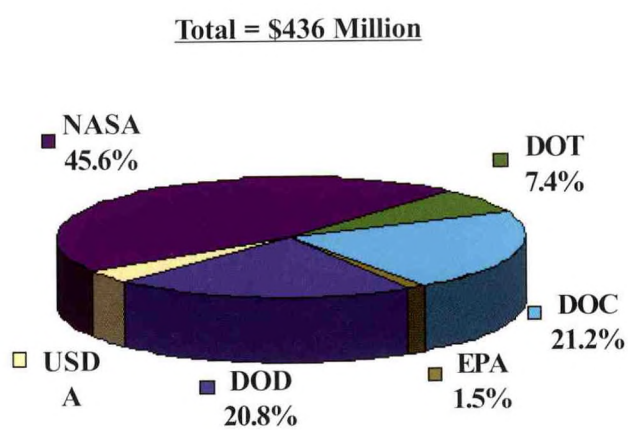

Figure ES-3. Agency Percent of Federal Budget for Supporting Research, FY 2001

Figure ES-3 depicts each agency's portion of the proposed federal supporting research budget. Unlike operations, DOC, DOD, and NASA account for the major share (87.6 percent) of the supporting research budget. Requests for increases in supporting research funds are: DOC 4.6 percent and DOT 26.5 percent. The DOD and NASA requests for supporting research funds decreases by 1.1 and 4.1 percent, respectively.

All agencies project a personnel total of 14,492 full-time equivalent (FTE) to be employed in federal meteorological operations in FY 2001. This figure represents a decrease of less than 1 percent from the 14,503 FTE employed in FY 2000.

MAJOR PROGRAMS--DOC, DOD, and DOT

Next Generation Weather Radar (NEXRAD). The NEXRAD Program which began in FY 1981 was responsible for procurement, installation, and operation of the Weather Surveillance Radar-1988 Doppler (WSR-88D). The first limited production WSR-88D system was installed at Oklahoma City, Oklahoma in May 1990 and commissioned 4 years later in February 1994. The original program plan called for a total of 161 radars. In response to a National Research Council report, three additional radars were added and raised the total to 164 radar sites. The last system in the basic procurement schedule was installed in June 1996.

By agency, as of June 2000, the DOC/National Weather Service had commissioned 123 sites, the DOD (USAF and Army) had commissioned 31 sites (within the states and overseas), and the DOT/FAA had commissioned 12 sites. DOD has three systems at Keesler AFB, Mississippi, for training; DOC/NWS has one each at the National Reconditioning Center, and NWS Training Center in Kansas City, Missouri and at the Operational Support Facility, Oklahoma City, Oklahoma.

Automated Surface Observing System (ASOS). The ASOS program, began in 1983, as a joint development effort between the DOC, DOD, and DOT/FAA. Installation of ASOS units started in 1991. As of June 2000, a total of 994 units have been purchased. The NWS has purchased, accepted, and commissioned 314 sites. The FAA has purchased 569 units, accepted 567 units, and commissioned 454 sites. The Navy has purchased, accepted, and commissioned 77 sites. The Air Force has purchased, accepted, and commissioned 34 sites. Collectively, a total of 879 ASOS sites have been commissioned.

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

Major agency systems classified as AWISs are: NOAA's Advanced Weather Interactive Processing System (AWIPS), FAA's Weather and Radar Processor (WARP); Air Force's New-Tactical Forecasts System (N-TFS) and Operational Weather Squadron Production System, Phase 2 (OPS-II); and Navy's Naval Integrated Tactical Environmental Subsystem (NITES).

In February 1997, the Secretary of Commerce approved the limited deployment of AWIPS. This decision authorized NOAA to procure and deploy 21 systems. The group of 21 limited deployment systems were installed in November 1997 through March 1998. A second group of 19 limited deployment systems were installed in June through August 1998. On April 9, 1998, the Secretary authorized full scale production and deployment of AWIPS, through Build 4.2, for the remaining 95 systems. Installation of these 95 systems began in September 1998 and was completed in June 1999. An Operational Test and Evaluation of the commissioning software (Build 4.2) was successfully conducted from mid-May through June 1999. AWIPS commissioning began in January 2000 and, as of June 2000, NWS had commissioned 141 AWIPS systems located at 121 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), and 7 national centers.

The FAA's Weather and Radar Processor (WARP) will greatly enhance the dissemination of aviation weather information throughout the NAS. WARP will automatically create unique regional, WSR-88D-based, mosaic products and send these products, along with other time-critical weather information, to controllers through the Advanced Automation System (AAS) as well as to pilots via the aeronautical data link.

The Air Force is modernizing and improving strategic, operational, and combat level systems. Modernization programs include the Observing System 21st Century (OS-21), N-TFS, OPS-II, Tactical Weather Radar, and Small Tactical Terminal which provides a single system for both garrison and deployed operations. These systems will replace AWDS and serve as an in-garrison system as well as a deployable "first-in" combat weather forecast capability. OS-21 will provide a much needed state-of-the-art life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. The manual section is intended for tactical operations and will continue upgrades begun under the Manual Observing System and Tactical

Meteorological Observing System modification programs. The Air Force purchased commercial off-the-shelf remote miniature weather sensors to provide accurate real-time weather information from forward unmanned locations to support Kosovo operations. OS-21 will continue to expand this capability.

The Navy continues procurement or upgrades of the five subsystems to the Naval Integrated Tactical Environmental System (NITES). These subsystems include: NITES I – Tactical Environmental Support System (TESS/NC), NITES II - Joint TESS Remote Workstation (J-TRWS) and Joint METOC Segment (JMS), NITES III - METOC Integrated Data Display System (MIDDS), NITES IV - Interim Mobile Oceanography Support System (I-MOSS), and NITES V - Allied Environmental Support System (AESS).

OTHER AGENCY PROGRAMS

For FY 2001, the Department of Agriculture (USDA) requested $28.1 million for meteorological operations ($12.6 million) and supporting research ($15.5 million). Operationally, the USDA supports specialized weather observation networks and also conducts an active supporting research program to ensure an abundance of high-quality agricultural commodities while minimizing the adverse effects of agriculture on the environment. Under supporting research, USDA focuses on the interactions of weather and climate with plant and animal production and water resources management.

The Department of the Interior's (DOI) FY 2001 request is $1.1 million primarily to support the Bureau of Land Management's remote automatic weather station (RAWS) program.

The budget request for the Environmental Protection Agency (EPA) remains level at $6.4 million to provide user-appropriate and scientifically credible air-quality meteorological programs to support regulatory applications.

Nearly all of NASA's funding in meteorology is for supporting research. The requested funding for supporting research in FY 2001 is $163 million, which is nearly 5 percent lower than the FY 2000 funding level. These funding levels are composed of the estimated meteorology share of the supporting research and analysis programs as well as Earth Observing System (EOS) and Earth Probe instruments, EOS science, and the EOS Data Information System elements of the NASA Office of Earth Science budget. Included in NASA's request is $35.25 million for special programs under the category of aviation weather supporting research.

The Nuclear Regulatory Commission's (NRC) request for $117,000 is mainly for operations. The NRC will dedicate these funds to obtain and analyze meteorological data and information related to the safe operation of nuclear facilities, and the protection of the environment, public health, and safety.

FEDERAL COORDINATION ACTIVITIES

Natural Disaster Reduction-OFCM hosted the 54th Interdepartmental Hurricane Conference, February 14-18, 2000 in Houston, Texas, to review the nation's hurricane forecast and warning program and to recommend program improvements. Houston, Texas was chosen to commemorate the 100th anniversary of the 1900 hurricane which devastated the Galveston/Houston area. The theme for the conference was "*20th Century Highlights and Prospects for the Future*". An important objective of the conference was to more closely link hurricane operations with ongoing research efforts. A ceremony commemorating the 1900 storm was planned in conjunction with the Galveston Historical Foundation and hosted by the Honorable Roger Quiroga, Mayor of Galveston, on Thursday afternoon, February 17, 2000.

Weather Information for Surface Transportation. The OFCM and Department of Transportation Federal Highway Administration (FHWA) co-sponsored "*Symposium on Weather Information for Surface Transportation: Delivering Improved Safety and Efficiency for Tomorrow*" was held November 30-December 2, 1999, at the Holiday Inn, Silver Spring, Maryland. This first event of its kind was attended by more than 120 individuals. Keynote speakers were Dr. Stephen Van Beek, Associate Deputy Secretary of Transportation, and Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere. The goal of the symposium was to establish the national needs and requirements for weather information. An initial draft of a requirements document will be completed Fall 2000.

Aviation Weather Forum. The OFCM and Department of Transportation Federal Aviation Administration (FAA) co-sponsored user forum "*Aviation Weather: Opportunities for Implementation*" was held July 25-26, 2000, at the Bethesda Ramada Hotel and Conference Center, Bethesda, Maryland. The forum brought together key government agency representatives, as well as a cross section of professionals representing commercial, business, and general aviation. Keynote speakers were Mr. Peter H. Challan, Deputy Associate Administrator for Air Traffic Services, FAA, and Mr. Scott B. Gudes, Deputy Under Secretary for Oceans and Atmosphere, Department of Commerce. The goal of the forum was to highlight work accomplished, identify opportunities for immediate or near-term implementation, and assess

where user and industry efforts are helping government agencies achieve the National Aviation Weather Program objectives.

Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community. The OFCM sponsored "*Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community*" was held June 6-8, 2000, at the Town Center Hotel, Silver Spring, Maryland. The workshop was attended by over fifty participants who represented nine federal agencies involved in dispersion modeling. The goal of the workshop was to bring users and developers of dispersion models together to improve the coordination in the development and operational use of dispersion models. This workshop provided an opportunity to assess the current state of dispersion modeling and to identify barriers that need to be overcome in order to meet the wide range of requirements.

Space Weather. During FY 2000, OFCM space weather groups prepared a second edition of the *National Space Weather Program Implementation Plan*. It was developed concurrently with the National Security Space Architect's Space Weather Architecture and describes the linkage to and incorporation of that architecture into the National Space Weather Program. It also builds on the previous Implementation Plan and reports on the significant accomplishments in research, operations, technology transition, education, and outreach. The Plan also updates the program's timelines and offers specific recommendations to carry the program forward.

National Hurricane Conference. OFCM worked with the National Weather Service to organize a panel on "*Improving Public Response to Hurricane Warnings*" for the April 17-21, 2000, National Hurricane Conference in New Orleans, Louisiana. The purpose of the panel was to elicit suggestions from the panel members and the conference attendees on how to improve public response. The panel encouraged cross-cutting participation by several conference groups (meteorology, emergency management, universities, media, Red Cross, insurance companies, etc.). Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere, was a keynote speaker for the National Hurricane Conference.

National Research Council/National Academy of Sciences. The first joint meeting between the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) and National Research Council National Academy of Sciences Board on Atmospheric Sciences and Climate (BASC) was held October 25, 1999, at the National Academy of Sciences Main Building on Constitution Avenue, Washington, District of Columbia. The meeting was co-chaired by Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere and FCMSSR Chairman, and Dr. Eric J. Baron, Professor at Pennsylvania State University and Co-chair of BASC. The meeting provided an opportunity to strengthen ties between the federal meteorological community, academia, and the private sector. Actions are being worked on and will be reported at the upcoming November 14, 2000, FCMSSR meeting, which will be attended by the Co-chair and Director of BASC.

BASC 21st Century Report Recommendation--A Strategy for Atmospheric Information. OFCM is planning a workshop to respond to and address Leadership and Management Recommendation 1 of the BASC report *The Atmospheric Sciences Entering the Twenty-First Century.* Important issues include: What criteria should govern the design of an optimal atmospheric information system? Should the government seek to recover costs of observations from the public by mechanisms other than taxes? Who is to be responsible for forecasts for critical activities such as agriculture and aviation? Should federal agencies be responsible for supporting research to improve forecasts for such critical activities? What is the appropriate role for academic research, both basic and applied, in such an evolving weather information system, and how should such research be supported so that it remains vigorous and contributes to national goals?

Committee on Environment and Natural Resources. OFCM continued to develop its interactions with the Committee on Environment and Natural Resources (CENR) Subcommittee on Natural Disaster Reduction (SNDR). OFCM and SNDR will co-sponsor a workshop on Risk Assessment and Cost-Benefit Analysis in late January or early February 2001. Also, regarding risk assessment, an OFCM senior meteorologist helped conduct a panel session on risk assessment for natural disasters at the 25th Annual Hazards Research and Applications Workshop, July 9-12, 2000, in Boulder, Colorado. An OFCM senior meteorologist will also serve on a two day focus group September 28-29, 2000, at FEMA's Emergency Management Institute in Emmitsburg, Maryland, to develop a classroom based, upper division college course on "Hazards Risk Assessment."

Department of Energy Meteorological Coordinating Council. OFCM continued its close liaison with the DOE Meteorological Coordinating Council (DMCC). OFCM plans to attend the joint meeting of the Subcommittee on Consequence Assessment and Protective Actions (SCAPA), the DMCC, and the Nuclear Utility Meteorological data User Group (NUMUG) in Las Vegas, Nevada, October 16-20, 2000. During the DMCC portion of the meeting,

OFCM will brief on OFCM activities, and results and actions from the OFCM sponsored "*Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community*" which was held June 6-8, 2000, in Silver Spring, Maryland.

American Meteorological Society and *The Weather Channel* Forum. OFCM participated in the "*Workshop on Policy Issues in Hurricane Preparedness and Response*" developed by the Atmospheric Policy Program of the American Meteorological Society and sponsored by *The Weather Channel*, June 6-7, 2000, at The National Press Club, Washington, District of Columbia. The workshop considered the following question: What policy changes are needed to produce weather services, media communications, and emergency management decisions that will optimize hurricane preparedness and response? The opening address of the workshop was given by Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere. An OFCM senior meteorologist briefed the forum on the recent National Hurricane Conference panel on Improving Public Response to Hurricane Warnings to assist the forum's deliberations concerning hurricane response.

American Meteorological Society. During FY 2000, OFCM joined eleven leading environmental science and service corporations in supporting undergraduate scholarships in the atmospheric and related oceanic and hydrologic sciences. The scholarships, awarded for the junior and senior years, are designed to encourage outstanding undergraduates to pursue careers in the fields covered by the awards. OFCM plans to continue this support in FY 2001. OFCM also supports American Meteorological Society endeavors by participating in AMS conferences and workshops and other environmental science education and outreach programs.

NATO Meeting. OFCM hosted a meeting of the NATO Military Committee Meteorological Group (MCMG) Working Group for Operations, Plans and Communications (OPC), June 27-30, 2000. MCMG is composed of national representatives and representatives of major NATO Commanders which provides meteorological policy guidance to the Military Committee, the major NATO Commanders, and the NATO nations. OPC addresses planning and operational issues for meteorological support to NATO exercises and operations and develops meteorological communications capabilities and standard procedures for communications and exchanging meteorological data.

Publications and OFCM's Website. The following plans and publications were prepared in hardcopy form and also placed on OFCM's website (*www.ofcm.gov*):

- *The Federal Plan for Meteorological Services and Supporting Research--FY 2000*
- *National Hurricane Operations Plan*
- *The National Space Weather Program: Implementation Plan (2nd Edition)*
- *54th Interdepartmental Hurricane Conference (Minutes)*
- *Proceedings for the Symposium "Weather Information for Surface Transportation: Delivering Improved Safety and Efficiency for Tomorrow"*
- *Proceedings of the "Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community"*
- *Proceedings of the Aviation Weather User Forum "Aviation Weather: Opportunities for Implementation"*

The following documents are planned for publication during FY 2001:

- *National Plan for Post-Storm Data Acquisition*
- *A National Framework for Volcanic Ash Hazards to Aviation*
- *The Federal Plan for Meteorological Services and Supporting Research--FY 2001*
- *National Hurricane Operations Plan*
- *55th Interdepartmental Hurricane Conference (Minutes)*
- *Proceedings for 2nd Symposium on Weather Information for Surface Transportation*
- *Proceedings for Risk Assessment and Cost-Benefit Analysis Workshop*
- *Proceedings for Severe Local Weather Workshop*
- *Proceedings for Workshop on BASC 21st Century Report Recommendation--A Strategy for Atmospheric Information*

During FY 2000, OFCM continued to make substantial progress on its use of the Internet. In addition to information about the office, OFCM has placed its current publications on its website, and keeps the website current with information regarding workshops and symposia being conducted by the office. OFCM will continue to make information available on the Internet during FY 2001.

THE LEGACY OF HURRICANE FLOYD--INLAND FLOODING AND A MASSIVE EVACUATION

INTRODUCTION

Hurricane Floyd was a large, intense Cape Verde hurricane that pounded the central and northern Bahamas and threatened the eastern coastline of the United States from Florida to North Carolina. Floyd was near the threshold of Category 5 intensity on the Saffir/Simpson Hurricane Scale as it approached the Bahamas and remained a strong Category 4 hurricane while heading north along the Florida Coast. Floyd then began to slowly weaken and paralleled the Atlantic coastline before turning north-northeast, making landfall near Cape Fear, North Carolina, on September 16, 1999, as a Category 2 hurricane. Hurricane Floyd caused over 3 million people to evacuate and produced a flood disaster of immense proportions in the eastern United States, particularly in North Carolina, as it moved up the east coast into New England. (Figure 1-1)

To put the inland flooding problem in perspective, this article will (a) examine the event from a historical viewpoint; (b) describe, in some detail, the meteorological impacts, the warning and forecast support, and the human and economic losses associated with Floyd; and (c) summarize the public's response from a behavioral standpoint.

During a session on Improving Public Response to Hurricane Warnings, held at the National Hurricane Conference in April 2000, Mr. John Gambel, Federal Emergency Management Agency's (FEMA) National Hurricane Program Coordinator, stated the massive evacuation by the public during Hurricane Floyd highlighted the serious problem that has been created by the migration of significant numbers of people to the United States coastal regions and the barrier islands. Sufficient plans do not exist and the transportation infrastructure was not adequate to handle an evacuation of this magnitude. The results of an assessment completed by FEMA and the United States Army Corps of Engineers following Hurricane Floyd were presented and provided revealing insights on how the public will respond to similar evacuations in the future.

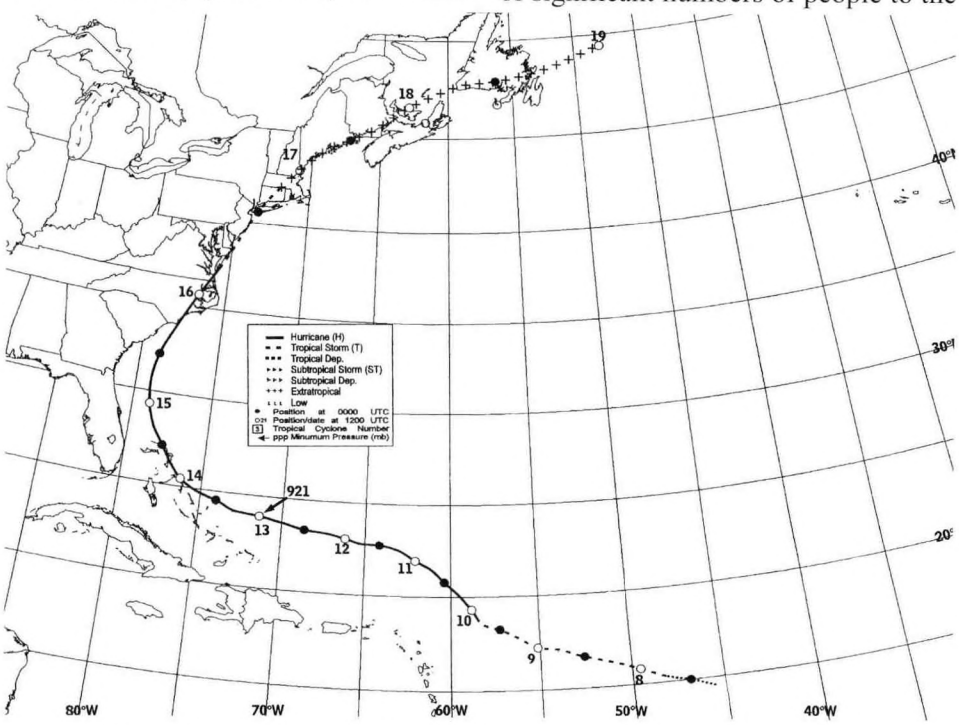

Figure 1-1. Best track of Hurricane Floyd - September 7-17, 1999.

This article was prepared by Mr. Robert Dumont, OFCM Staff.

HISTORY OF THE INLAND FLOODING PROBLEM

In a recent study, Dr. Edward Rappaport, Tropical Prediction Center/National Hurricane Center (TPC/NHC), reported a total of 600 fatalities in the contiguous United States and its coastal waters associated with Atlantic tropical cyclones during 1970-1999. Drowning accounted for 479 deaths, or 82 percent, of the fatalities with wind-related events responsible for most of the others. When it comes to hurricanes, it is obvious that wind speeds do not tell the whole story. Hurricanes produce storm surge, tornadoes, and often the most deadly of all--inland flooding. Intense rainfall is not directly related to the wind speed of tropical cyclones. In fact, some of the greatest rainfall amounts occur from weaker storms that drift slowly or stall over an area. Examples of tropical cyclones that produced significant impacts after moving inland include:

- Tropical Storm Charley (1998) dropped 16.83 inches of rain on Del Rio, Texas, on August 23, 1998, easily surpassing the previous daily record of 8.79 inches. Charley was responsible for 13 freshwater drowning deaths.

- Tropical Storm Alberto (1994) drifted over the Southeast United States and produced torrential rainfall--more than 21 inches of rain fell at Americus, Texas. Thirty-three people drowned and damages exceeded $750 million.
- Hurricane Agnes (1972) produced floods in the Northeast United States which contributed to 122 deaths and $6.4 million in damages--the largest loss in the last 30 years.
- In 1955, Hurricane Diane brought inland flooding to Pennsylvania, New York, and New England. Diane contributed to nearly 200 deaths and $4.2 billion in damages.

Loss of life from Atlantic tropical cyclones has occurred inland hundreds of miles from the coast. While most deaths in the eastern United States occurred from the Appalachian Mountains eastward, many locations not suffering losses in the last 30 years were simply fortunate to be out of harm's way. For example, Hurricane Camille (1969) caused a large loss of life in West Virginia after its center had moved about 700 miles over land and Hurricane Hazel (1954) caused inland deaths northward from North Carolina to Canada.

In the last 30 years, freshwater floods from excessive tropical cyclone-related rains led to about 300 deaths in inland counties and dominate the fatality totals for those areas. A disproportionately large percentage (75-80 percent) of the children killed by tropical cyclones drowned in freshwater floods. Such meteorological and hydrological factors as storm speed (e.g., Alberto's near stall over Georgia), size and character of the precipitation field, orography, interactions with other weather features, including low-level frontal zones (e.g., Floyd) or disturbances aloft (e.g., Agnes), soil nature, and wetness (e.g., Hurricane Dennis' rains preceding Floyd in North Carolina) were important in determining the magnitude of the inland flooding threat. Combining coastal and inland statistics, 59 percent of the deaths occurred by drowning in freshwater.

SYNOPTIC HISTORY AND METEOROLOGICAL IMPACT AT LANDFALL

Hurricane Floyd can be traced back to a tropical wave that emerged from western Africa on September 2, 1999. Overall, the system was broad and disorganized, yet easily recognizable as a synoptic-scale entity. Floyd slowly strengthened and became a hurricane by 1200 UTC, September 10, while centered about 200 nautical miles (nm) east-northeast of the northern Leeward Islands. After strengthening to nearly Category 3 status early on the September 11, the hurricane weakened to 85 knots around 0000 UTC on September 12. Early on the 12th, rising mid- and upper-tropospheric heights to the north of Floyd forced a turn toward the west which marked the beginning of a major strengthening episode (this phenomenon has also been observed with many past hurricanes; e.g., Hurricane Andrew--1992). Maximum sustained winds increased from 95 knots to 135 knots and the central pressure fell about 40 millibars (mb) by early September 13. From 0600-1800 UTC on September 13, Hurricane Floyd was at the top end of Category 4 intensity.

One potential contributor to the significant strengthening of Floyd was the presence of enhanced upper ocean heat content along its track. Analyses from the Physical Oceanography Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) showed relatively high values of heat content just to the east of the Bahamas a day or two before Floyd passed through the area.

Hurricane Floyd was moving toward the central Bahamas until late on the 13th when the heading became west-northwestward. The eye passed just 20-30 nm northeast and north of the San Salvador and Cat Islands on the night of September 13. Floyd's eyewall passed over central and northern Eleuthera on the morning of September 14 and, after turning toward the northwest, Floyd struck Abaco Island on the afternoon of the 14th. By the time Hurricane Floyd hit Abaco, it had weakened somewhat from its peak but was still a borderline Category 3 or 4 hurricane.

As a mid- to upper-tropospheric trough over the eastern United States eroded the subtropical ridge over the extreme western Atlantic, Floyd continued to gradually turn to the right. The center of the storm paralleled the central Florida coast, passing about 95 nm east of Cape Canaveral around 0900 UTC on September 15. By the afternoon, Floyd was abeam of the Florida/Georgia border and headed northward toward the Carolinas.

Although there was a fluctuation in intensity related to an eyewall replacement event, overall the intensity of Floyd diminished from September 13-15. Environmental causes for intensity change are not entirely understood, but two large scale factors probably contributed to the gradual decline: (1) the entrainment of drier air at low levels from the northwest and (2) increasing south-southwesterly vertical shear. As Floyd neared the North Carolina coast late on September 15, its maximum winds decreased below Category 3 status.

After turning toward the north-northeast with forward speed increasing to near 15 knots, Hurricane Floyd made landfall near Cape Fear, North Carolina, at 0630 UTC, September 16, as a Category 2 hurricane with estimated maximum winds near 90 knots. Floyd was losing its eyewall structure as it made landfall and continued to

accelerate north-northeastward over extreme eastern North Carolina on the morning of September 16 and over the greater Norfolk, Virginia, area around 1500 UTC that day. Floyd then weakened to a tropical storm and moved swiftly along the coasts of the Delmarva peninsula and New Jersey on the afternoon and early evening of September 16 and reached Long Island by 0000 UTC, September 17. By that time, the storm's speed had increased to near 29 knots. The storm decelerated as it moved into New England and became more involved with a frontal zone that existed along the Atlantic seaboard. The system then took the form of a frontal low and, thus, became extratropical by the time it reached the coast of Maine at 1200 UTC, September 17.

Heavy rainfall preceded Floyd over the Mid-Atlantic states due to a pre-existing frontal zone and the associated overrunning. Hence, although the tropical cyclone was moving fairly quickly, precipitation amounts were very large. Rainfall totals as high as 15 to 20 inches were recorded in portions of eastern North Carolina and Virginia. At Wilmington, North Carolina, the storm total of 19.06 inches included a 24-hour record of 15.06 inches. Totals of 12 to 14 inches were observed in Maryland, Delaware, and New Jersey. A new record of 6.63 inches was set in Philadelphia for the most rainfall in a calendar day. In southeastern New York, rainfall totals were generally in the 4 to 7 inch range, but there was a report of 13.70 inches at Brewster. Totals of nearly 11 inches were measured in portions of New England. (Figure 1-2)

As Floyd made landfall in North Carolina, the winds ahead of the eye drove water onshore on the Atlantic shoreline and westward in the Pamlico and Albemarle Sounds and up several of the rivers located on the west side of the sounds. The highest storm surge values ranged from 5.5 to 9.0 feet. The 9.0 foot storm surge maximum (the highest observed in Floyd) was reported by an observer near Wilmington, North Carolina. The maximum observed storm surge plus the astronomical tide component totaled 10.3 feet--the actual water elevation observed.

A number of tornadoes were sighted in eastern North Carolina. There was a confirmed tornado in Bertie County and another in Perquimans County which destroyed two houses and damaged several others. At least ten tornadoes were reported by spotters in the Newport/Morehead City County Warning Area and these apparently caused some structural damage. Four tornadoes or funnel clouds were seen in the Wilmington area, but no damage was apparent.

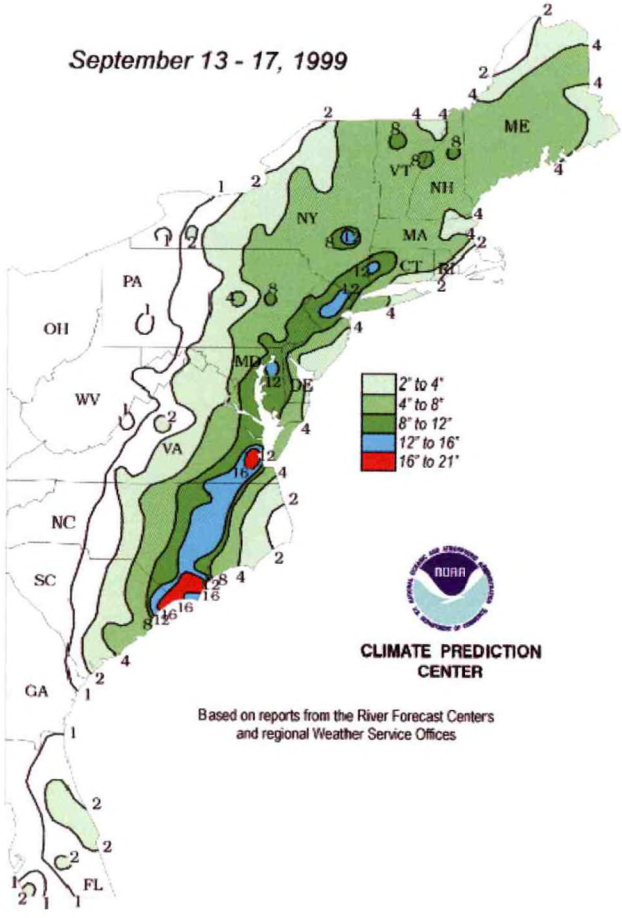

Figure 1-2. Total precipitation (inches) from Hurricane Floyd.

WARNING AND FORECAST SUPPORT

Tropical Prediction Center/National Hurricane Center

When averaged over the entire lifetime of the hurricane, the TPC/NHC track forecasts for Floyd were excellent. The average official forecast errors at 12, 24, 36, 48, and 72 hours were 32, 61, 84, 84, and 120 miles, respectively. These errors are much smaller than the most recent 10-year average errors of 55, 103, 147, 189, and 279 miles. The overall average official forecast errors for Floyd were small; however, the official forecasts for the period when hurricane warnings were in effect for the United States (5 p.m. on September 13 to 11 a.m. on September 16) were average. The average 24-hour track forecast error for this latter period was roughly the same as the most recent 10-year average. In general, the track forecasts for this period had a westward bias and were somewhat slow.

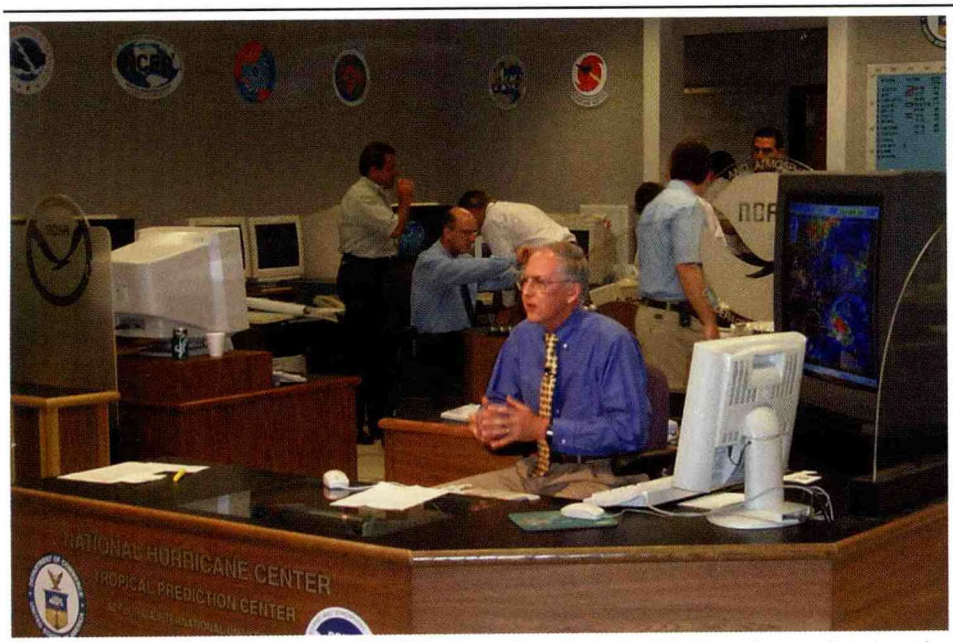

Figure 1-3. Mr. Max Mayfield, Director, Tropical Prediction Center/National Hurricane Center, provides an update to a national television audience.

The official intensity forecasts averaged over Floyd's lifetime were good. The average official errors at 12, 24, 36, 48, and 72 hours were 12, 17, 20, 20, and 14 mph, respectively. These errors were considerably smaller than the errors of forecasts based upon climatology and persistence (the usual benchmark for evaluation of forecast skill) of 15, 22, 28, 32, and 44 mph. After Floyd reached its maximum intensity, the official forecasts did not predict enough weakening. From September 13 on, the wind speed was over-forecast in the advisories at nearly every forecast interval.

As Hurricane Floyd moved toward south Florida and then up the East Coast, the TPC/NHC (Figure 1-3) issued tropical storm warnings from as far south as the Florida Keys to as far north as Merrimack River, Massachusetts. At various times during the storm, hurricane warnings were posted along sections of the coastline from Florida City, Florida, to Plymouth, Massachusetts. In reality, only a small fraction of the coast with hurricane warnings experienced sustained hurricane-force winds. Hurricane warnings were issued for the coast of North Carolina at 11 p.m. on September 14--about 27 hours prior to the arrival of the eyewall in the Cape Fear area. For the coasts of South Carolina and North Carolina, hurricane warnings were issued at least 24 hours before the onset of tropical storm-force winds.

River Forecast Centers (RFC)

Hurricane Floyd's track impacted three NWS RFCs: the Southeast (SERFC), the Mid-Atlantic (MARFC), and the Northeast (NERFC). Recognizing the potential for severe flooding early on, all three centers extended their operating hours from 16- to 24-hours a day prior to the arrival of Floyd. On Tuesday, September 14, SERFC and MARFC issued contingency forecasts based on 9 inches of forecasted rainfall. This information was coordinated internally via telephone and fax to impacted Weather Forecast Offices (WFO) and communicated to many emergency managers. These forecasts indicated the risk of major-to-record flooding if that amount of rainfall were to occur.

RFCs issued timely river forecasts through the River Forecast product. The accuracy of these forecasts increased as flood crests approached. The three affected RFCs issued a total of 252 river forecasts. These forecasts were issued daily and updated every 6 hours, or when needed. The initial flood warnings were low and were raised with the ingest of observed rainfall and higher Quantitative Precipitation Forecasts (QPF). Official forecasts provided lead times of several hours to a few days prior to the onset of flooding, depending on the response times of the rivers. Lead times of up to several days were achieved on river crest forecasts. In addition, hydrologists at all RFCs coordinated closely with WFOs and local officials.

Weather Forecast Offices (WFO)

The NWS WFOs have the responsibility of issuing timely meteorologic and hydrologic warnings, forecasts, and statements. These offices are the contact for state, county, and local agencies as well as the media and the general public. During Hurricane Floyd, 13 WFOs were impacted with high winds and tornadoes, coastal flooding, flash flooding, and river flooding, or a combination of all these events. Six WFOs (Wakefield, Virginia; Raleigh, North Carolina; Wilmington, North Carolina; Morehead City, North Carolina; Mt. Holly, New Jersey; and Brookhaven, New York) had record river flooding, record rainfall, or both. While the rainfall from Floyd was the primary contributor to the devastating flooding, rainfall from Hurricane Dennis, a week before, set the stage for these events.

Nineteen official NWS river forecast points reported record flooding due to the rainfall from Dennis and Floyd. Another 36 forecast points recorded major flooding. Record river flooding occurred in both the Southeast (North Carolina, South Carolina, and Virginia) and the Northeast (New Jersey and Pennsylvania). WFOs issued a total of 300 Flood Warnings and Flood Statements for flooding associated with Hurricane Floyd.

The coastal North Carolina WFOs

were severely impacted by Hurricane Floyd. River flooding due to Dennis was ongoing when Floyd brought high winds, tornadoes, and coastal and flash flooding. The day before Floyd made landfall, WFOs Morehead City and Wilmington, North Carolina, issued 28 tornado warnings in a 10-hour period. Hurricane-spawned tornadoes were occurring at the same time as hurricane-force winds and flash flooding. The flash flooding was more severe than residents had ever remembered.

The northeast WFOs did not have the long-lasting flooding of the South but were affected by record flash and urban flooding. A particular problem in the Northeast region, where population density is high and terrain is flat, is the extreme effect just a foot rise along some area tributaries can have on the areal extent of flooding. This situation was particularly a problem in portions of New Jersey. The result was property damage affecting thousands of homes and businesses.

Every affected WFO issued either a Special Weather Statement or Flood Potential Statement to highlight the high flood danger 30 to 48 hours before flooding by Floyd began. Flood or Flash Flood Watches were issued by all affected WFOs from 12 to 36 hours before the onset of flooding. A total of 532 Flash Flood Warnings were issued by the 13 WFOs for areas from northeast South Carolina through New England. Verification of these warnings for the 13 WFOs combined was outstanding.

All WFOs impacted by Floyd were proactive in their efforts to get the word out early. Perhaps most appreciated by emergency officials were WFO efforts in using conference calls to provide advance notice and continual updates of Floyd's track and resulting river flood crests. All WFOs made advance "heads up" calls to emergency management officials from 2 to 5 days before rainfall from Floyd began. With the realization that Floyd would cause massive inland flooding, emergency officials were again briefed days in advance. As the events of Floyd unfolded, WFOs continued to conduct once- or twice-a-day conference calls with state and county emergency officials. These conference calls typically occurred just following the internal NWS conference calls, thus providing emergency officials with the latest updates on Floyd.

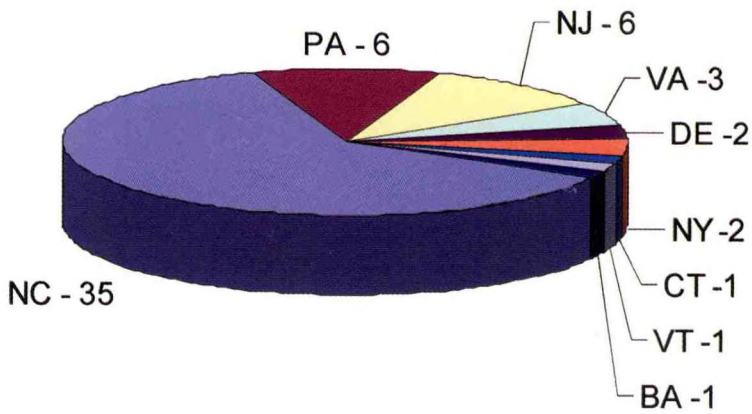

Figure 1-4. Distribution of fatalities along Hurricane Floyd's path.

Floyd's Impact

There were 57 deaths directly attributable to Floyd with 56 in the continental United States and 1 on Grand Bahama Island (Figure 1-4). Most of these deaths (50) were due to drowning in freshwater flooding. A massive rescue effort is credited with saving another 1,400 people from Floyd's flood waters. In fact, 32 of the 50 deaths (64 per cent) occurred when the individuals were in, or attempting to abandon, their vehicles. Over the last 30 years, at least 138 victims (23 percent) died in this manner and almost all of these incidents occurred in association with freshwater-flooded roads.

In addition to the loss of life, the wrath of Floyd resulted in the destruction of homes, businesses, and infrastructure; loss of livestock and crops; and a disruption of commerce. For North Carolina alone, FEMA's documented economic impact which only includes losses to businesses and agriculture was $6 billion--$1 billion for business structures, $4 billion in lost business revenues, and $1 billion in agricultural losses.

For the agricultural business sector, Hurricane Floyd had a significant regional impact on individual farmers and other agricultural producers. Crop losses were in excess of $500 million--over half of which were in cotton and tobacco. Almost 3 million chickens and turkeys, 30,000 hogs, and 1,000 cattle were lost. Farm equipment and facility losses were over $300 million. Losses to the fisheries and forestry industries totaled $25 million and $90 million, respectively. Following Floyd, federal and state officials anticipated that flood waters would have widespread, long-term environmental effects on the health, welfare, and usability of the impacted areas. Fortunately, according to FEMA's economic impact assessment, the environmental effects appear to have been less than anticipated due in part to the quick action of emergency response teams.

Flood insurance claims from Hurricane Floyd will rank as the second-highest. As of March 1, 2000, the National Flood Insurance Program (NFIP), which is administered by FEMA, had paid more $310 million to settle 14,614 claims for flood damage that occurred as Hurricane Floyd dumped torrential rains from Florida to Maine. With approximately

9,500 claims still open, FEMA expects that the total insurance payments from Floyd will reach $460 million. In the history of the NFIP, this total is only exceeded by the Louisiana floods of May 1995 which resulted in nearly $584 million in paid claims.

While making its trek along the Atlantic coastline, Hurricane Floyd was responsible for the largest peacetime evacuation in United States history and over 3 million people responded to the evacuation order. Following Hurricane Floyd, the United States Army Corps of Engineers, Savannah District, and FEMA-Region IV contracted for a Hurricane Floyd Assessment to review hurricane evacuation studies utilization and information dissemination. The following information is excerpted from that report:

PUBLIC RESPONSE--A BEHAVIORAL ANALYSIS

Method

During the months following Hurricane Floyd, nearly 7,000 members of the public were interviewed to (a) document and explain their response to Floyd and (b) anticipate their behavior in future evacuations. The sample was divided into 11 clusters of counties from Dade County, Florida, through North Carolina's Outer Banks. The sampling was designed to conform to hurricane planning regions used by the respective states. The regions were:

- Eastern North Carolina--the Outer Banks and counties along Albemarle and Pamlico Sounds
- Southeastern North Carolina--from the South Carolina border to the Outer Banks, including Wilmington
- Northern South Carolina--including the Myrtle Beach "Grand Strand" area
- Central South Carolina--including Charleston and vicinity
- Southern South Carolina--including the Beaufort area
- Northern Georgia--including Savannah
- Southern Georgia--including Brunswick and Camden County
- Northeast Florida--including Jacksonville and St. Augustine
- East-Central Florida--including Daytona Beach and Melbourne
- Treasure Coast Florida--including Palm Beach and Fort Pierce
- Southeast Florida--Dade and Broward Counties

Each of the 11 clusters were then stratified into four risk areas: (1) areas which would flood due to storm surge in Category 1 hurricanes, (2) areas which would flood due to storm surge in stronger hurricanes, (3) areas of coastal counties which would not flood from storm surge in any hurricane, and (4) non-coastal counties bordering the coastal counties.

Evacuation Participation Rates

There was considerable variation in evacuation rates among the 11 survey areas. Evacuation (i.e., leaving one's home to go to some place safer) was highest in Georgia and southern South Carolina. In the Category 1 zone, up to 90 percent left the Savannah area and numbers were almost that high around Brunswick, Georgia, and Beaufort, South Carolina. Rates dropped off gradually both north and south, with major dropoffs for the Treasure Coast and southeast Florida and eastern North Carolina areas. Evacuation was also high in Georgia and in the Beaufort, South Carolina, area for people living in areas subject to surge inundation in storms stronger than Category 1 with 75-85 percent leaving from those areas. Again, the dropoff was gradual in both directions, with more significant decreases at the end of the study area. In Florida, only Category 1 surge areas were ordered to evacuate. In Georgia and southern South Carolina, entire coastal counties were told to evacuate. Participation rates for Category 1 surge zone areas are detailed in Figure 1-5.

In the Charleston, Beaufort, and Savannah areas, evacuation from non-surge zones was unusually high. In all three areas, all or most of the counties were told to evacuate. Even away from those locations, between 20-40 percent of the non-surge residents left in most survey areas. These "shadow" evacuees contributed to the large number of people on evacuation routes. Evacuation in adjacent non-coastal counties were also surprisingly high and averaged approximately 25 percent. In the Charleston vicinity,

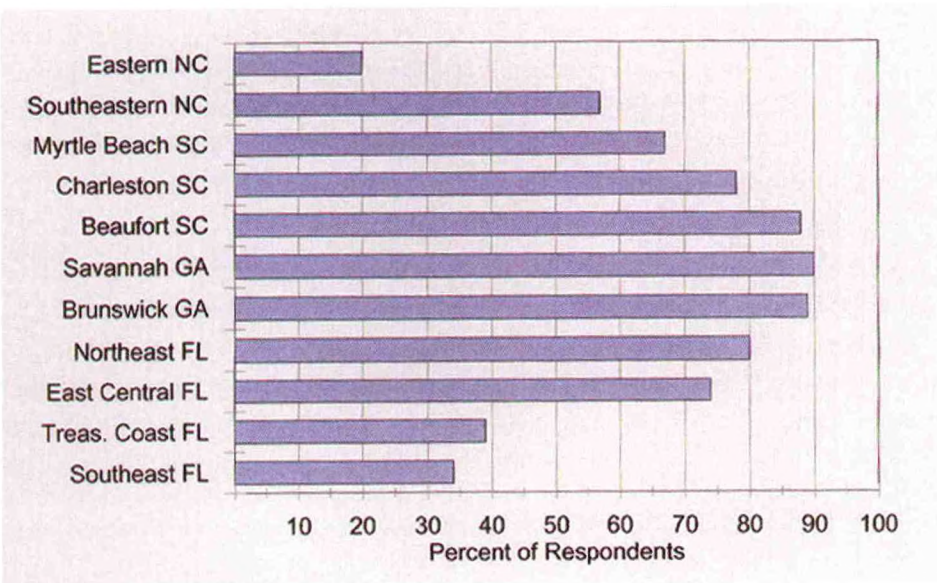

Figure 1-5. Evacuation participation rates for Category 1 Storm Surge Zones.

almost half of the residents in adjacent non-coastal counties evacuated their homes. When asked why they left, most respondents gave a combination of reasons; such as, evacuation notices from public officials, storm severity, and recommendations from friends, family, and the media. When asked which was the main influence on their decision to evacuate, information coming from public officials (or which they perceived to be coming from public officials) had the greatest effect for most people. With the exception of the two southernmost Florida locations, a majority of people living in the Category 1 surge areas said they heard officials call for their evacuation. The highest percentage that actually evacuated was in the Charleston area--80 percent. Some residents living in non-surge areas also believed they heard officials say that they should evacuate. In Georgia and parts of South Carolina, more than 60 percent of the non-surge residents of coastal counties said they heard official evacuation notices which applied to them, and that was probably correct for most. In other states and in non-coastal counties, up to 25 percent of the respondents believed they heard officials say that they should evacuate, and that was probably not correct, except for people living in mobile homes. These results emphasize the fact that it is extremely important for officials to reach those for whom the evacuation notices are intended and to avoid confusing those for whom the notices are not intended.

One reason there was substantial evacuation from areas not targeted by officials is that many residents of non-surge areas perceived themselves to be vulnerable to major hurricanes. When asked whether their homes would be safe in a 125 mph hurricane 20-40 percent of the people living in coastal county non-surge areas believed their homes would be unsafe from storm surge and waves; 25-60 percent believed their homes would be unsafe, considering both wind and surge. Even in adjacent non-coastal counties 15-35 percent believed their homes would experience dangerous flooding from storm surge and waves; 40 percent to nearly 60 percent believed their homes would be unsafe, considering both wind and water.

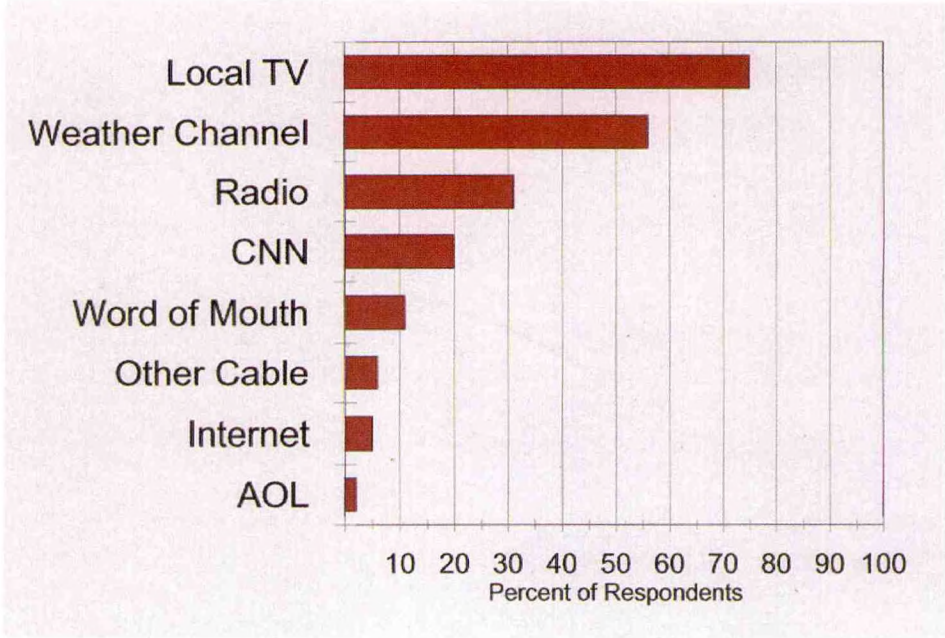

Figure 1-6. Survey results regarding relied upon sources of information.

The importance of perception cannot be overlooked. People who believe their homes are unsafe are much more likely than others in their same risk area to evacuate. In most locations, people who believe their homes are unsafe are about twice as likely as others to leave. This is a good thing when applied to people who really need to evacuate, but it can contribute to overcrowding on evacuation routes and in shelters when applied to people who could stay home and be safe.

There are various ways to reach the public with evacuation and vulnerability information during a hurricane threat, but local television and *The Weather Channel* are the most-relied upon sources of information in most locations. Eventually, the Internet and online computer services will gain increased importance, but currently less than 10 percent of coastal residents say they rely heavily on those sources for hurricane threat information. Survey results are depicted in Figure 1-6.

Evacuation Destinations

Evacuation congestion is made worse when large numbers of evacuees leave the local area rather than simply going to safe locations within their own community. During Hurricane Floyd, an unusual percentage of evacuees went to destinations outside their own county. Among evacuees from Category 1 and larger surge zones, as many as 98 percent left their own county and in 8 of 11 study locations more than 70 percent did the same. These percentages are unusually high, but even in non-surge areas, more than half of the evacuees went out-of-county in 8 of 10 non-surge locations. In adjacent non-coastal counties, more than half of the evacuees went out of the county from half the survey sites.

When asked why they left their county, for many evacuees the answer was obvious. Georgia and some South Carolina locations evacuated entire coastal counties, so there were no places to go within those counties and still comply with evacuation notices. Moreover, in those locations, residents appear to appreciate and acknowledge

Figure 1-7. Evacuation order in South Carolina resulted in major traffic congestion along Interstate 26. (Photo: Post & Courier; Charleston, South Carolina)

the vulnerability of their counties. In many locations, public shelters are not operated in coastal counties or even in the next tier of counties inland. Respondents gave three predominant explanations for going out of county: (1) that was the location of friends or relatives with whom they could stay, (2) the storm was strong enough so they wanted to get far away from it, and (3) they had to go as far as they did to find vacant lodging. For most locations, the decision to go out of county was influenced more by hearing from public officials rather than by other messages heard through the media or information from friends and relatives.

The majority of evacuees went to homes of friends and relatives which is common in most evacuations. Between 20 and 30 percent in most locations went to hotels and motels; fewer than 10 percent (closer to 5 percent in most locations) went to public shelters. Approximately 40 percent of the evacuees said they heard announcements concerning the availability of shelters or refuges after they left home, but fewer than 10 percent of those who heard took advantage of the offers.

Transportation

Of all the vehicles available to evacuating households, between 65 and 75 percent were used in Floyd--a typical statistic for most evacuations. Evacuees in Charleston had the longest average travel times--almost 9 hours. Beaufort and the two Georgia sites also had average travel times exceeding 6 hours. When asked how long they expected the evacuation to take, the expectations of the evacuees were, not surprisingly, shorter than reality. When asked the reasons for the traffic delays, most blamed the large volume of traffic and too many people leaving at the same time. In most locations, fewer than 30 percent attributed the delays to poor management. The exception was Charleston, where over 40 percent blamed management. Some people mentioned the need to reverse traffic lanes along evacuation routes. Evacuees were asked whether they would be willing to delay their departure in an evacuation to let people in areas of greater risk leave first in order to avoid congestion (Figure 1-7). Between 80 and 90 percent said they would.

Between 35 and 60 percent of the evacuees said they used interstate highways for a substantial portion of the evacuation and between 70 and 90 percent said they were familiar with the road systems in the areas through which they were evacuating. This response implies that evacuees would be able to take advantage of information about alternative routes if they received the information. In Floyd, between 20 and 55 percent of the evacuees said they heard announcements about evacuation route problems before leaving home. Of those hearing the announcements, approximately 30 percent changed their plans concerning routes to use. As evidenced by their behavior in Floyd, evacuees appear to be receptive to route announcements. In fact, when asked whether they would be willing to use a route other than the one they had planned to use if urged to do so by emergency officials, more than 70 percent said they would.

Next Time

A key question asked following Hurricane Floyd was whether the unpleasant experiences during the evacuation would deter people from leaving in future hurricane events. Certainly many evacuees had bad experiences, but when asked to describe the sorts of difficulties they endured, most respondents, even in Charleston, reported none other than aggravation. The most common complaint was a lack of restroom facilities, followed by food and water. It is important for public safety officials to recognize the fact that the people who complain about events by contacting agencies, writing to newspapers, and so forth don't constitute a random sample of the public.

When asked what they would do differently if faced with a similar hurricane threat in the future, fewer than 20 percent of the evacuees in most locations said they would not evacuate next time. Some of the evacuees didn't

need to evacuate during Floyd, so their inclination to stay in the future is not negative. Most of those who do need to go can be convinced to do so in an actual threat. The most common response when asked what they would do differently was to leave earlier next time.

SUMMARY AND CONCLUSIONS

Inland flooding from landfalling tropical cyclones is a clear and present danger. We cannot afford to let the media spotlight and public attention diffuse and shift away from the ending drama at the coast to other current events rather than following the usually weakening tropical cyclone while it moves inland. The National Weather Service performed superbly during Hurricane Floyd, but we look to future meteorological research efforts to improve our capabilities. The Hurricane Landfall and Quantitative Precipitation Forecasting components of the United States Weather Research Program are indicative of the significance of the tropical cyclone threat to this country, as well as our focused commitment to minimize the impacts of that threat in the future.

During the National Hurricane Conference session on Improving Public Response to Hurricane Warnings, Dr. Jay Baker, Department of Geography, Florida State University, who participated in the Hurricane Floyd Assessment, described four important points with regard to understanding the public's response.

(1) Evacuation orders are the most effective means for evoking a response from the public, as long as they are heard and understood by those who need to respond.

(2) People must understand their own personal vulnerability. One problem is that the public tends to underestimate high risks and overestimate low risks, as evidenced during Floyd.

(3) We need to tell and convince people they need to only go a certain distance to be safe, and

(4) We need to understand and use the public's sources of information to disseminate information.

Recommendations for the future include:

- Better education of the public regarding their vulnerability.
- Wording evacuation notices to ensure they are not misinterpreted and effectively disseminating them.
- Telling people what to do and why.
- Not forgetting those who didn't leave but should have.

As demonstrated by the experiences during Hurricane Floyd, facilitating the transportation of those who evacuate is another challenge. During the Office of the Federal Coordinator for Meteorology (OFCM) sponsored 54th Interdepartmental Hurricane Conference in February 2000, Mr. Howard R. Chapman, Charleston Area Rapid Transit Authority, elaborated on the problems that were experienced in the Charleston area. He also described the plans to alleviate these problems in the future which include a lane reversal plan for Interstate 26, plans for the Governor to stagger evacuations, and a call for earlier, initial evacuations. Their plans also provide for constant information about conditions to be disseminated by National Public Radio and educational television and for improved access to secondary roads as alternate routes of evacuation. The key to the future success of our Nation's response to landfalling hurricanes is to act on the lessons learned from the past. Hurricane Floyd certainly provided federal, state, and local officials with a wealth of lessons learned that will help refine current and shape future plans.

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SECTION 2

RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The tables in this section summarize budgetary information of the federal government for Fiscal Years 2000 and 2001. The funds shown are those used to provide meteorological services and associated supporting research that has as its immediate objective the improvement of these services. Fiscal data are current as of the end of June 2000 and are subject to later changes. The data for FY 2001 do not have legislative approval and do not constitute a commitment by the United States Government. The budget data are prepared in compliance with Section 304 of Public Law 87-843, in which Congress directed that an annual horizontal budget be prepared for meteorological programs conducted by the federal agencies.

AGENCY OBLIGATIONS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Table 2.1 contains fiscal information, by agency, for meteorological operations and supporting research. The table shows the funding level for Fiscal Year (FY) 2000 based on Congressional appropriations, the budget request for FY 2001, the percent change, and the individual agencies' percent of the total federal funding for FY 2001 and FY 2001.

DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 2001 is $28.1 million for operations and supporting research and represents no change from FY 2000. The USDA assists the Department of Commerce in determining farmers' needs for weather information and in disseminating the information to them. Major USDA activities related to weather observations include incremental modernization of the snow telemetry (SNOTEL) system operated by the Natural Resources Conservation Service (NRCS) and the replacement of manual fire rating stations with remote automated weather stations (RAWS) by the Forest Service. The SNOTEL and RAWS networks provide cooperative data for NOAA's river forecast activities, the irrigation water supply estimates, and Bureau of Land Management operations.

For supporting research, USDA requested $15.5 million to focus on the interactions of weather and climate with plant and animal production and water resources management. The goal of supporting research is to develop and disseminate information and techniques to ensure an abundance of high-quality agricultural commodities and products while minimizing the adverse effects of agriculture on the environment. The research budget does not include the coordinated effort with EPA on ultraviolet radiation. The Forest Service supports a research program, initiated in 1988, for a long-term monitoring network to assess potential effects of global climate change and variability on forest health and productivity. Work also continues in forestry ecological systems modeling.

DEPARTMENT OF COMMERCE (DOC)

All reported DOC meteorological activities are within the National Oceanic and Atmospheric Administration (NOAA). The NOAA FY 2001 total congressional request of $1.44 billion for meteorological programs represents an increase of 8.3 percent over the FY 2001 appropriated funds.

NOAA's FY 2001 operations and supporting research requests for major line-office activities are described below:

Weather Services

Mission. The National Weather Service (NWS) provides weather, water, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community.

Introduction. America's vulnerability to weather-related hazards is rising as more of the population moves into weather harm's way and national and global economies become more complex. Approximately 40 percent of all Americans, some 100 million people, currently reside in areas of high risk to natural disasters, with the number climbing yearly. Today, 90 percent of all presidentially declared disasters are weather and flood related. Moreover, water resources are the lifeblood of the economy and our standard of living. During the next century, weather will continue to impact our lives and significantly impact the United States economy. In recognition of this fact, the NWS was recognized by National Partnership for Reinventing Government (NPR) as one of thirty-two high impact federal agencies. By working with our partners, especially the private sector and emergency management community, NWS is striving to ensure our products and services are responsive to the needs of the American public.

TABLE 2.1 METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH COSTS*, BY AGENCY

(Thousands of Dollars)

	Operations			% of FY2001	Supporting Research			% of FY2001	Total			% of FY2000	% of FY2001
AGENCY	FY2000	FY2001	%CHG	TOTAL	FY2000	FY2001	%CHG	TOTAL	FY2000	FY2001	%CHG	TOTAL	TOTAL
Agriculture	12600	12600	0.0	0.6	15500	15500	0.0	3.6	28100	28100	0.0	1.1	1.0
Commerce/NOAA(Subtot)	1243121	1349401	8.5	60.2	88520	92599	4.6	21.2	1331641	1442000	8.3	53.3	53.9
NWS	656942	713232	8.6	31.8	19583	23054	17.7	5.3	676525	736286	8.8	27.1	27.5
NESDIS	565122	612644	8.4	27.3	10319	11585	12.3	2.7	575441	624229	8.5	23.0	23.3
OAR	3000	3152	5.1	0.1	47184	44455	-5.8	10.2	50184	47607	-5.1	2.0	1.8
NOS	10540	12950	22.9	0.6	10540	12950	0.0	3.0	21080	25900	22.9	0.8	1.0
NOAA Corps	7517	7423	-1.3	0.3	894	555	-37.9	0.1	8411	7978	-5.1	0.3	0.3
Defense(Subtot)	384178	440609.8	14.7	19.7	91546	90505.1	-1.1	20.8	475724	531114.9	11.6	19.1	19.8
Air Force	169233	184831	9.2	8.2	35714	33184	-7.1	7.6	204947	218015	6.4	8.2	8.1
DMSP**	55769	81944	46.9	3.7	21207	25372	19.6	5.8	76976	107316	39.4	3.1	4.0
Navy	123489	124797	1.1	5.6	18457	18706	1.3	4.3	141946	143503	1.1	5.7	5.4
Army	35687	49037.8	37.4	2.2	16168	13243.1	-18.1	3.0	51855	62280.9	20.1	2.1	2.3
Interior/BLM	1100	1100	0.0	0.0	0	0	0.0	0.0	1100	1100	0.0	0.0	0.0
Transportation(Subtot)	416849.1	433242.2	3.9	19.3	25561.9	32341.8	26.5	7.4	442411	465584	5.2	17.7	17.4
CG	6000	6000	0.0	0.3	0	0	0.0	0.0	6000	6000	0.0	0.2	0.2
FAA	410849.1	427242.2	4.0	19.1	22536.9	30341.8	34.6	7.0	433386	457584	5.6	17.4	17.1
FHWA	0	0	0.0	0.0	3025	2000	-33.9	0.5	3025	2000	-33.9	0.1	0.1
EPA	0	0	0.0	0.0	6400	6400	0.0	1.5	6400	6400	0.0	0.3	0.2
NASA	3888	3960	1.9	0.2	207250	198650	-4.1	45.6	211138	202610	-4.0	8.5	7.6
NRC	180	117	-35.0	0.0	0	0	0.0	0.0	180	117	-35.0	0.0	0.0
TOTAL	2061916.1	2241030	8.7	100.0	434777.9	435995.9	4.0	100.0	2496694	2677025.9	7.2	100.0	100.0
% of FY TOTAL	82.6%	83.7%			17.4%	16.3%			100.0%	100.0%			

*The FY 1999 funding reflects Congressionally appropriated funds; the FY 2000 funding reflects the amount requested in the President's FY 2000 budget submission to Congress.

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

The FY 2001 Budget Request supports the funding and program requirements to enable the NWS to better use science to serve our citizens and fulfill its vision of becoming America's "no surprise" weather service. This vision states that the NWS will produce and deliver forecasts you can trust when you need them most, use cutting-edge technologies, provide services in a cost-effective manner, strive to eliminate weather-related fatalities, and improve the economic value of weather information. In FY 2001, the NWS will continue its mission of providing weather and flood warnings and forecasts to the public and improve the overall warning lead times for tornadoes, severe thunderstorms, and flash floods, as well as improve the accuracy of hurricane landfall predictions.

The NWS contributes to three of NOAA's Strategic Plan goals: (1) Advance Short-Term Warning and Forecast Services, (2) Implement Seasonal to Interannual Climate Forecasts, and (3) Predict and Assess Decadal to Centennial Change. The NWS request also supports investments in the Natural Disaster Reduction Initiative (NDRI) as well as the NOAA Climate Observations and Services Initiative.

Budget Overview

Overall, the NOAA request includes a total of $710.2 million for the National Weather Service, a net increase of $56.3 million above the FY 2000 appropriation. The request includes a total of $634.9 million for Operations, Research, and Facilities (OR&F) and $75.4 million for Procurement, Acquisition, and Construction (PAC). In FY 2001, the budget priorities for NWS include sustaining current services, replacing obsolete observing systems, infusing new technology, and enhancing service to the Public.

Operations, Research, and Facilities.

The FY 2001 budget includes a request of $634.9 million, an increase of $33.5 million over the FY 2000 appropriation. The increase allows NWS to maintain current services in FY 2001. Specifically, the increase of $33.5 million includes $16.0 million for Mandatory Pay Raises and Inflationary Costs, $8.4 million to sustain base operations, $2.0 million for Weather Forecast Office (WFO) maintenance, $2.3 million to sustain the Co-Operative Observer (COOP) Network, $5.8 million for Advanced Weather Interactive Processing System (AWIPS) Operations and Maintenance (O&M), -$0.4 million for NEXRAD O&M, and -$0.8M for one-time program terminations. The specific details are outlined below:

- Mandatory Pay and Inflationary Costs (+$16.0M). NOAA requests an increase of $16.0 million to fund Adjustments to Base (ATBs) for NWS. The increase will fund the FY 2001 federal pay raise of 3.9 percent and annualize the FY 2000 pay raise of 4.8 percent as well as provide inflationary increases for certain non-labor activities, including service contracts, field office lease payments, and rent charges from the General Services Administration (GSA).
- Sustain NWS Base Operations (+$8.4M). NOAA requests an increase of $8.4 million to support NWS field office operations and maintain current services in FY 2001. The $8.4 million increase includes the following critical base activities:

•• Continue Weather Service Office Operations (+$.9M)--Funding is required to sustain operations at certain Weather Services Offices previously slated for closure. These offices include Ft. Smith, Arkansas; Huntsville, Alabama; Williston, North Dakota; and Erie, Pennsylvania. The offices will remain open until all necessary follow-on studies are completed and the Secretary of Commerce makes a final decision on each closure action.

•• Provide FAA/ASOS Augmentation (+$1.8M)--To comply with the FAA Observation and Aviation Service Standards, NWS is required to perform manual weather observations to augment and backup ASOS observations at certain airports across the Nation. Due to staff reductions achieved under the NWS Modernization, the workload associated with ASOS augmentation cannot be absorbed by the current NWS field office staff. The $1.8 million will provide the necessary contract support to perform the function at 17 sites.

•• Sustain NOAA Weather Radio Network (NWR) (+$3.0M)--NWS requires funding to operate and maintain 110 NWR transmitters which will be added to the network in FY 2000 and FY 2001. Current partnership agreements require the NWS to operate and maintain transmitters purchased by states and localities, the private sector, and the federal government. The NWR network is a critical for transmitting NWS warning and forecast messages to the public by providing advance notice for severe weather events.

•• Provide Network Security (+$.8M)--NWS requires funding to procure and install emergency network security hardware at the National Centers for Environmental Prediction (NCEP). The security system will prevent service interruptions from cyber and hacker attacks. NCEP receives over 25 hacker attacks per week and the number is doubling every 3 months.

•• Ensure Workplace Safety (+$.7M)--NWS requires funding to replace unsafe hydrogen generators which are used to inflate weather balloons at field offices in

Alaska. Currently, the generators present a significant safety risk to NWS employees.

•• Sustain Field Observations (+$1.2M)--NWS requires funding in FY 2001 to sustain its current suite of surface observation equipment which are critical for local weather and flood forecasting. To avoid catastrophic loss of data, NWS is planning to replace surface data collectors used to report observations from stream gages, river gages, and remote weather observation stations.

• Weather Forecast Office (WFO) Maintenance & Repair (+$2.0M). NWS requests an increase of $2.0 million for WFO Maintenance & Repair. This request will allow NWS to fund recurring maintenance contracts and address a backlog of over $7.0 million in deferred maintenance actions. WFOs require a significant investment in recurring and cyclic maintenance, including replacement of major facility support systems, such as power backup and heating, ventilation, and air conditioning (HVAC). The request will allow NWS to protect the $250 million capital investment in modernized facilities in accordance with GSA and private industry standards. In FY 2001, NWS will complete high priority repair actions at 20 field offices.

• Cooperative Observer Network (+$2.3M). NOAA requests an increase of $2.3 million to sustain the Nation's cooperative observer network. The cooperative observer network is a nationwide network of over 11,000 volunteer-operated weather observing sites used by NOAA to maintain the Nation's climate record and to provide data to local NWS field offices. In a recent report, the National Research Council recommended that NOAA take immediate steps to sustain and modernize this critical network. The instruments used to detect daily minimum and maximum temperatures as well as rain gage recording devices for measuring precipitation are virtually obsolete and increasingly costly to maintain. In FY 2001, NWS plans to begin a five-year program to modernize the entire current network. The $2.3 million will allow NWS to replace 900 rain gages and 200 temperature sensors in FY 2001.

• Advanced Hydrologic Prediction System (AHPS). In FY 2001, NOAA will also continue implementation of AHPS in the Mississippi and Ohio River Basin, focusing on high priority flood prone areas. The OR&F request includes a total of $1.0 million for this critical service improvement program. Once deployed, AHPS will significantly improve flood forecasting and water resource management by extending river stage forecasts from days to months in the future. AHPS will also provide new river forecast information which can be used by water resource and emergency managers for risk-based decision-making. AHPS will save lives and provide over $600 million in annual savings to the United States economy.

• Next Generation Weather Radar (NEXRAD) Operations & Maintenance (-$0.4M). NOAA requests a decrease of $0.4 million to provide recurring operations and maintenance for the current NWS network of 123 NEXRAD units. The NEXRAD network provides nationwide Doppler radar coverage, improving detection of severe weather and floods and increasing the warning lead time for tornadoes. This level of funding will provide for logistics, utilities, and system maintenance to ensure the operational availability of the NEXRAD network.

• Advanced Weather Interactive Processing System (AWIPS) Operations & Maintenance (+$5.8M). NOAA requests an increase of $5.8 million to provide recurring operations and maintenance for the fully deployed network of 152 AWIPS systems. FY 2001 funding is required to address recurring communications, systems obsolescence, and hardware maintenance support costs associated with build 4.2 operations.

• Automated Surface Observing System (ASOS) (+$0.02M). NOAA requests an increase of $0.02 million to operate and maintain the NWS network of 314 ASOS units. ASOS provides the weather forecaster with critical surface observations to improve weather warning and forecast services. ASOS also provides critical data to support the aviation community and climate information users.

• Procurement, Acquisition, and Construction (PAC). As indicated above, the NOAA request includes a total of $75.4 million for NWS PAC programs, an increase of $19.8 million over the FY 2000 appropriation. The specific requests are listed below:

•• NEXRAD (+$1.3M)--NOAA requests an increase of $1.3 million over the FY 2000 appropriation. In FY 2001, NWS will continue product improvement efforts by infusing new technology into the current NEXRAD radar network. The current system processor utilizes obsolete technology developed in the late 1980s. As a result, a number of new detection techniques, that are ready for operational use, cannot run on the present system. Combined with AWIPS build 5.0 technology, the NEXRAD Product Improvement (NPI) will allow NWS forecasters to improve the tornado warning lead time by 5 minutes (11 minutes

to 16 minutes) and improve the accuracy of severe storm forecasts by over 20 percent. In FY 2001, the NWS will complete hardware retrofits on a total of 50 NEXRAD radars.

- ASOS (+$1.3M)--NOAA requests an increase of $1.3 million over the FY 2000. In FY 2001, NWS will continue product improvement efforts, testing, and deploying new sensor capabilities. Specifically, NWS will replace obsolete processors on 250 ASOS systems and continue replacement of the all-weather rain gage and ice free wind sensor which are critical to aviation users.
- AWIPS (+$1.4M)--NOAA increase of $1.4 million over the FY 2000 appropriation. In FY 2001, NWS will complete the 2nd of a 3-year effort to develop and deploy AWIPS build 5.0 software. Combined with NPI technology, AWIPS build 5.0 software will allow NWS forecasters to improve the tornado warning lead time by 5 minutes (11 minutes to 16 minutes) and improve the accuracy of severe storm forecasts by over 20 percent. The NOAA request also includes funding to provide a backup Network Control Facility (NCF).
- Central Computer Facility (+$4.0M)--NOAA requests an increase of $4.0 million over the FY 2000 appropriation. The increase includes $2.0 million to operate and maintain the Class VIII supercomputer which is currently located on the Census Facility in Bowie, Maryland. The increase is necessary to provide required operations and maintenance as well as provide the necessary communications infrastructure to support the Class VIII. The increase also includes $2.0 million to obtain computing resources to improve and expand operational climate forecasts. In FY 2001, NWS is proposing to expand the current Climate Threats (Drought, Fire, Flooding) Assessment and Extreme Heat Index from 14 days to 3 months. In addition, NWS utilize additional computing capacity to improve forecasts for El Niño, La Niña, and other climate oscillations.
- Evansville, Indiana mitigation (+$5.5M)--NOAA requests an increase of $5.5 million to acquire, deploy, and install a Doppler weather radar for the Evansville, Indiana. In FY 1999, the Modernization Transition Committee (MTC) recognized a gap in radar coverage for Southern Indiana and Illinois. The MTC requested the NWS develop an action plan to address this issue before the closure certification could be finalized for the Evansville Weather Service Office.
- Radiosonde Replacement Network --NOAA will continue the replacement and modernization of the upper air radiosonde network. The PAC request includes a total of $7.0 million for this activity in FY 2001. The radiosonde network provides critical upper air observations which are the principal data source for all weather forecasts. These funds will enable NWS to exercise the first option year of the replacement systems contract to begin full deployment of the ground receiving stations, replace the remaining IBM XT microcomputers with modern PCs, continue software development, and procure surface instruments that will provide ground-based measurements at the point of balloon release.
- NOAA Weather Radio (NWR) (+$6.2M)--NOAA requests an increase of $6.2 million to upgrade and expand the NWR network to meet the Vice President's Goal of 95 percent coverage for the United States population. The NWR network is the sole government-owned and -operated radio network for the direct broadcast of weather warnings and forecasts, and other hazard information to the public. In FY 2001, NWS proposes to install 30-50 new transmitters at high priority sites across the country. In addition, NWS proposes a one-time investment of $1.7 million to improve the current NWR voice transmissions.
- NWS Weather Forecast Office (WFO) Construction--Within the overall PAC request, NOAA requests a total amount of $9.5 million to continue this critical facilities modernization program. In FY 2001, NWS will continue construction activities for the new weather office in Caribou, Maine, and Key West, Florida. In addition, NWS will continue efforts to modernize the current Alaska Tsunami Warning Center as well as replace employee housing in St. Paul, Alaska.

Environmental Satellite, Data, and Information Services

Proposed funding for FY 2001 includes an increase in the Polar-Orbiting Satellite Program of $23.4 million and an increase in the Geostationary Satellite Program of $25.2 million. These changes allow for continuation of procurements to provide the spacecraft and instruments, launch services, and ground systems necessary to assure continuity of environmental satellite coverage. The FY 2001 budget request will maintain a system of polar-orbiting satellites that obtains global data and a system of geostationary satellites that provides near-continuous observations of the Earth's western hemisphere. Funding is included for NOAA's share of the converged NOAA and Department of Defense (DOD) polar-orbiting system

that will replace the current NOAA series and the DOD Defense Meteorological Satellite Program (DMSP).

A total of $4.0 million is requested to continue the Ocean Remote Sensing Program which began in FY 1995. During the next several years, NOAA will acquire data from foreign and other non-NOAA satellites that will provide measurement of ocean currents, surface winds and waves, subsurface temperature and salinity profiles, ice thickness and flows, and other marine factors.

An increase of $3.3 million is included to maintain basic mission services including maintenance and operation of satellite ground facilities; provision of satellite-derived products; and conduct of research to improve the use of satellite data.

An increase of $5.5 million is requested for NOAA's lead role in the interagency Global Disaster Information Network (GDIN) and an offsetting decrease is included as the result of eliminating funds for the Global Winds Demonstration Program (-$2,3 million).

Budgetary changes netting to a decrease of $7.6 million are included in the Environmental Data Management System subactivity. The changes include an increase in base operating funding (+$2.8 million). Decreases include elimination of funding for Regional Climatic Centers (-$2.8 million) and reductions in funding for Data Preservation (-$4.2 million) and the National Coastal Ocean Data Development Center (-$3.7 million).

Office of Atmospheric Research

Requested funding for FY 2001 for Weather Research and Solar-Terrestrial Services and Research is $47.61 million--a net decrease of $2.58 million. Increases included a small base adjustment of $0.31 million to partially cover inflationary cost increases as well as a very small base restoration of $0.18 million. There also were programmatic increases of $1.0 million for the United States Weather Research Program, directed principally toward improving hurricane track predictions, and $0.1 million for the Space Weather Information Dissemination Program. Three program decreases were also requested: $1.39 million to terminate an add-on for incorporating wind profile data into forecast models, $1.85 million to terminate a second add-on for the "STORM" Program at the University of Northern Iowa, and $0.92 million to terminate a third add-on for the Radiophysics Laboratory at Dartmouth College.

DEPARTMENT OF DEFENSE (DOD)

The DOD total budget request for FY 2001 is $531.1 million. This total represents an increase of 11.6 percent in the funding level from FY 2000. Specific highlights for each of the military departments are described below:

United States Air Force

United States Air Force (USAF) resources for meteorological support fall under four categories: general operations, general supporting research, DMSP operations, and DMSP and National Polar-orbiting Operational Environmental Satellite System (NPOESS) supporting research. The Air Force request (including DMSP) for FY 2001 is $325.3 million.

General Operations. The operations portion of the FY 2001 budget request is $184.8 million and represents a large portion of the environmental support to the DOD. These funds will pay for weather and space environmental support to the USAF (both active duty and reserve components), the United States Army, nine unified commands, and other agencies as directed by the Chief of Staff of the Air Force. Over 4,900 people conduct these activities at over 200 worldwide locations. These people include active duty military, Air Force reservists, Air National Guard weather flight personnel, weather communications and computer specialists, and civilians. General operations fund the salaries of these people providing weather support, and the day-to-day operations and maintenance costs for the support they provide.

General Supporting Research. The FY 2001 budget request for Air Force supporting research is $33.2 million. The Air Force continues development of the Cloud Depiction and Forecast System II (CDFS II) and the Global Theater Weather Analysis and Prediction System (GTWAPS), and research and development will begin on the Tactical Weather Radar (TWR). CDFS II will expand the computer processing capability of the current CDFS at the Air Force Weather Agency (AFWA) and will build a high resolution, worldwide cloud database which will ingest and exploit all weather satellite and sensor data received at AFWA. GTWAPS will provide AFWA and the DOD a theater modeling capability to support the warfighters. A variety of other research efforts will investigate the electrodynamics of the Sun and Earth's magnetosphere, ionospheric dynamics, mesoscale meteorology, visible and infrared properties of the environment, and cloud parameterization and prediction.

DMSP Operations. Though funding for DMSP comes from the Air Force, this system is the major source of space-borne meteorological data for the military services and other high-priority DOD programs. Environmental data from DMSP sensors is also distributed to the NWS, National Environmental Satellite, Data, and Information Service (NESDIS), the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the Naval Oceanographic Office (NAVOCEANO), and AFWA according to the Shared Processing Program agreement.

The operations portion of the FY 2001 budget request is $81.9 million. The major portion of this funding is for on-orbit operations, tactical terminal maintenance, and long-haul communications. These funds also pay operations costs for one dedicated command and control facility. DMSP funds for 66 military and civilian personnel associated with the operation of, and to a much smaller extent, the procurement of the DMSP system.

DMSP and NPOESS Supporting Research. The FY 2001 budget for DMSP R&D is $25.4 million. The funds will be used for launch vehicle integration; system integration and testing; and mission sensor calibration, validation, and algorithm development efforts. The FY 2001 DOD R&D budget for NPOESS is $76.7 million. FY 2001 funds will be used for system architecture studies and independent risk reduction and technology development efforts, and to begin critical sensor and algorithm development. NPOESS is scheduled to be available in 2008 as a backup to the final launch of the NOAA polar-orbiting satellites and DMSP satellites. This system will exploit advanced hardware and software technologies to produce a more reliable, longer-lived spacecraft with greater mission capability.

United States Navy

The United States Navy FY 2001 budget request for meteorological programs is $143.5 million. The request includes $124.8 million for operational programs and $18.7 million for supporting research.

The Navy Meteorology and Oceanography (METOC) program is truly unique. Focusing support in the highly environmentally complex coastal/littoral regions around the globe, Navy METOC is required to provide an assessment of the impact of weather and ocean phenomena on weapon systems. Additionally, and just as important, Navy METOC provides for safe flight and navigation in support of Naval, joint, and combined forces operating throughout the world's oceans. This is done with a cadre of highly-trained military and civilian personnel, schooled in both the sciences and warfighting applications. By teaming with and leveraging the efforts of other agencies and activities, Navy METOC meets these challenges in a most cost-effective manner, providing a full spectrum of products and services with only about 5 percent of the Federal weather budget.

The Navy METOC program is required to provide comprehensive and integrated weather and ocean support worldwide. The Oceanographer of the Navy sponsors programs in four closely related disciplines--meteorology, oceanography, geospatial information and services, and precise time and astrometry. All are used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, and to provide a decisive tactical or strategic edge by exploiting the physical environment to optimize the performance and efficiency of platforms, sensors, and weapons.

Owing to the crucial interrelationship of the oceans and the atmosphere, the Navy requires various oceanographic products to provide the requisite meteorological services. In addition to aviation and marine METOC support, the Navy provides a variety of unique services on demand, such as electro-optical, electro-magnetic and acoustic propagation models and products, METOC-sensitive tactical decision aids, and global sea ice analyses and forecasts.

Support to Navy operations is provided under the direction of the Commander Naval Meteorology and Oceanography Command located in Stennis Space, Mississippi. Naval METOC support starts with sensing the battlespace physical environment and culminates with weapons arriving on target and personnel operating in the battlespace without being adversely affected by physical environmental phenomena. Operational support for the Navy and Marine Corps includes the day-to-day provision of meteorological and oceanographic (METOC) products and services. As Naval operations in the littoral increase, Navy METOC support is directed towards providing on-scene capabilities to personnel that directly furnish environmental data for sensor and weapon system planning and employment. These on-scene capabilities are key elements for enabling the warfighters to take advantage of the natural environment as part of battlespace management.

Navy METOC systems acquisition is accomplished through the Space and Naval Warfare Systems Command, San Diego, California. Several major METOC operations support systems are being procured or undergoing upgrades.

Navy METOC Research and Development (R&D) is cooperatively sponsored by the Oceanographer of the Navy and the Chief of Naval Research. This area is not generally system-specific; instead, Navy R&D efforts typically have applications to meteorological, oceanographic, and/or tactical systems. Navy's tabulation of budget data includes R&D funding for basic research, applied research, demonstration and validation, and engineering and manufacturing development.

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

United States Army

The United States Army is requesting $49.04 million for operational support and $13.2 million in research and development in FY 2001. Operational support increases approximately $12.4 million over the FY 2000 expenditures, research decreases about $2.9 million from the previous year, and staffing increases slightly. The cost increases in operational support are found mainly in the $13 million increase in systems acquisition costs from FY 2000 to FY 2001 at Army Materiel Command.

United States Army Europe estimates requirements of $2.9 million to fund weather operations during FY 2001, with $2.66 million going for operational support, $240,000 for special programs.

Training and Doctrine Command (TRADOC) has requested approximately $1.6 million for FY 2001. TRADOC will spend $1.47 million for operations support and $86,000 in FY 2001 for special programs costs related to instructors, evaluators, and operators at the Artillery, Aviation, and Intelligence Schools. The Artillery School at Ft. Sill will receive approximately $1.1 million of these monies to conduct operational soundings, support 24 military and civilian personnel, and to conduct training using the AN/TMQ-41 Meteorological Measuring Set (MMS).

Army Materiel Command will request a total of $34.3 million for FY 2001. $11.3 million will go for research and development and $23 million for systems acquisition. Developmental and testing costs associated with the MMS Profiler were $5.2 million in FY 2000 and will be $4.8 million in FY 2001. The Communications Electronics Command (CECOM) will spend $11.2 million to buy additional MMS's for the National Guard in FY 2001. The IMETS continued fielding of Block II systems in FY 2000. An IMETS budget of $7.02 million was approved to fund the completion of a total of 27 mounted systems and initiate development of an IMETS Light Configuration. In basic meteorological research the Army Research Laboratory, Battlefield Environment Division, basic research stays about constant at near $3.6 million. The Army Research Office saw a small decrease from $1.36 million to $1.15 million from FY 2000 to 2001 for basic research. The Small Business Innovative Research Program and the Defense University Research Instrumentation Program (DURIP) were provided funds for selected research projects. Last year's input for AMC inadvertently included research personnel in the agency personnel listings. This year's tables have been corrected to reflect the actual number of operations personnel.

The Eighth United States Army estimates requirements of $1.32 million to fund weather operations during FY 2001. This includes $710,000 for Army ARTYMET operations, $5,000 for the upgrade and maintenance of new FALOP systems, $80,000 for the purchase of new automated COTS observing systems for the DMZ area, and $520,000 for USAF weather support.

Forces Command will spend approximately $8.05 million in FY 2001 for Operations Support. Of this amount, $0.46 million will be spent for facilities, supplies, and travel for FORSCOM weather teams and $7.58 million will be in support of FORSCOM ARTYMET operations.

Space and Missile Defense Command (SMDC) activities will require $2.8 million for operational support and $0.5 million for supporting research in FY 2001. SMDC will spend $420,000 in operational support at the High Energy Laser Systems Test Facility (HELSTF) for contract services to operate and maintain the instrumentation, equipment, and facilities to support the atmospheric sciences/meteorological mission. HELSTF will also spend approximately $26,000 in systems acquisition for repair and replacement of meteorological instrumentation and for data services. Contract support services to operate the Kwajalein Missile Range will be approximately $2.2 million for operations support and $0.1 million for special weather programs for FY 2001. Supporting research activities at the Space and Missile Defense Battle Laboratory (SMDBL) will be $0.35 million for FY 2001 to provide post-Advanced Warfighting Experiment analysis and documentation.

The United States Army Special Operations Command (USASOC) provides Army funding, traditionally through a command level Unfunded Requirement (UFR), to the 10th Combat Weather Squadron (10 CWS) for operations and maintenance of equipment used by Special Operations Weather Teams (SOWTs) providing weather support to USASOC Major Subordinate Commands. The FY 2000 UFR was $115,000. $115,000 is planned to support the FY 2001 weather requirements as well.

It is anticipated that FY 2001 funding for weather-related environmental research efforts at United States Army Research Institute of Environmental Medicine (USARIEM) will continue at or near the FY 2000 level.

DEPARTMENT OF THE INTERIOR (DOI)

The DOI funding request for FY 2001 is $1,100,000. This figure is for meteorological operations and support of the Bureau of Land Management (BLM) remote sensing requirements for Remote Automatic Weather Station (RAWS) and Lightning Detection Programs. Normal operations and maintenance of the restructured Fire RAWS program is approximately $800,000 beginning this year. (This amount includes per-

sonnel, vehicles, per diem, normal procurement, and facilities).

The BLM optimization effort in RAWS will continue in 2001. Major efforts are underway among the Wildland Fire Agencies to consolidate our efforts in Fire Weather and National Fire Danger Rating Support. Continued optimization will take place over the next few years. Subsequent operational cost savings will be used to replace aging equipment and upgrade sensors packages. Proposed changes in lightning detection operations will further reduce the out-year expenditures in this program. Coordination between DOI agencies and the USDA Forest Service regarding combined meteorological requirements for the National Wildland Fire support functions is ongoing. During the coming geographic area review efforts, interagency RAWS replacement coordination will continue to maximize National Fire Danger Rating System (NFDRS) sampling points and minimize the total number of systems required in the West.

DEPARTMENT OF TRANSPORTATION (DOT)

The meteorological programs for the Federal Aviation Administration, Federal Highway Administration, and the United States Coast Guard for FY 2001 are described below:

Federal Aviation Administration (FAA)

The FAA request for aviation weather in FY 2001 is $457.6 million for both operations and supporting research; the FY 2000 funding was $433.4 million. The changes in the budget are increases for operations (acquisition and operational support) of $10.9 million to $427.2 million. Also, supporting research has increases of $7.8 million to $30.3 million.

In FY 2001, system acquisitions increases by 9.7 per cent to $122.6 million. This change is a mix of new systems coming on in their procurement while some other programs are decreasing as they are fielded and leave the acquisition process. Individual programs with changes greater than $2 million are listed below:

Programs	Changes ($ Millions)
Systems Acquisition:	
Operational and Supportability Implementation System (OASIS)	15.7
Weather and Radar Processor (WARP)	9.6
Terminal Doppler Weather Radar (TDWR)	-4.2
New Generation Runway Visual Range (NGRVR)	-3.3
Operations Support:	
Contract Weather Observations (CWO)	-11.3
Flight Service Stations	6.3
ASOS Maintenance	6.0
Weather Message Switching Center (WMSC)	2.5
Aviation Weather Research	8.5

The request for funding in FY 2001 increases by $7.3 million to $300.1 million. The change reflects a large decrease in costs for CWOs and large increases in manpower salaries. Other changes are smaller and reflect normal adjustment to support costs both up and down.

Federal Highway Administration (FHWA)

The total FHWA request for surface transportation weather programs in FY 2001 is $2.3 million all of which will be used for supporting research and special programs.

In 1999, the FHWA began documentation of road weather requirements which will serve as the basis for the majority of future work in this area. This work includes addressing the technical aspects of the road transportation system (including weather data collection, processing and dissemination) as well as the institutional challenges surrounding system implementation. These institutional challenges encompassed coordination within state and local Departments of Transportation as well as across the transportation and meteorological communities. With regard to technical areas of interest, data collection efforts will include increased coverage of road condition observations and incorporate road weather data (e.g., pavement and subsurface observations) into broader meteorological observation networks. Better processing includes the application of higher resolution weather models and the development of road condition prediction models (e.g. heat balance models) that are needed to develop the appropriate transportation weather information. In addition, surface transportation decision-makers require weather information disseminated in formats that are easily understood and in which human factors issues have already been incorporated. This need will be achieved through the development of improved road weather decision support systems. Finally, the FHWA will continue to develop outreach and training course material for program delivery, training, and promotion.

United States Coast Guard (USCG)

All of USCG's funding for meteorological programs is for operations support. For FY 2001, the requested funding level is $6 million. (The Coast Guard does not have a specific program and budget for meteorology--all meteorological activities are accomplished as part of general operations.) The Coast Guard's activities include the collection and dissemination of meteorological and iceberg warning information for the benefit of the marine community. The Coast Guard also collects coastal and marine observations from its shore stations and cutters, and transmits these observations daily to the Navy's Fleet Numerical Meteorology and Oceanography Center and NOAA's National Weather Service. These observations are used by both the Navy and NOAA in gener-

ating weather forecasts. The Coast Guard also disseminates a variety of weather forecast products and warnings to the marine community via radio transmissions. Coast Guard shore stations often serve as sites for NWS automated coastal weather stations, and the National Data Buoy Center provides logistics support in deploying and maintaining NOAA offshore weather buoys. The International Ice Patrol conducts iceberg surveillance operations and provides warnings to mariners on the presence of icebergs in the North Atlantic shipping lanes.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of the EPA'S funding of meteorological programs is for supporting research. The anticipated funding level in FY 2001 for directed meteorological research is $6.4 million which is the same as the FY 2000 funding level, which was a 13 percent increase over the FY-1999 level. This level was incremented in FY 2000 due to increased attention being paid to the effect of airborne toxics and particulate matter on human health.

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

The funding for the grants program will remain at $100 million in FY 2001. The augmented grants program will fund research in areas including ecological assessment, air quality, environmental fate and treatment of toxics and hazardous wastes, and exploratory research. The portion of these grants that will be awarded for meteorological research during FY 2001 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $6.4 million listed above for directed meteorological research.

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

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Nearly all of NASA's funding in meteorology is for supporting research. The requested funding for supporting research in FY 2001 is $163 million, which is nearly 5 percent lower than the FY 2000 funding level. These funding levels are composed of the estimated meteorology share of the supporting research and analysis programs as well as Earth Observing System (EOS) and Earth Probe instruments, EOS science, and the EOS Data Information System elements of the NASA Office of Earth Science budget.

The Earth Science Enterprise has articulated a set of science questions which its observational programs and research, modeling, and analysis activities are directed at answering. NASA plans to meet its immediate commitments and ensure the success of the EOS Terra, AQUA, AURA and IceSAT missions. In addition, NASA is committed to deliver of a functioning data and information system to support the processing, archival, and distribution of data products from these missions. In the Earth Probes program, increased requirements are funded to reflect the rephasing which is consistent with the selection of the Earth System Science Pathfinder (ESSP) Cloudsat and Picasso-Cena missions and the impacts associated with changing the launch vehicle for the Vegetation Canopy Lidar mission. NASA is also trying to establish a healthy and viable Science program to take full advantage of the satellites that will be launched this year and the remaining 16 that will be built and launched during the next four years. In addition to ensuring a robust science program, this budget maintains a vigorous Advanced Technology program that supports development of key technologies to enable NASA's mid-term and long-term science missions. In addition to the baseline technology program, which includes the New Millennium Program (NMP), Instrument Incubator Program (IIP), and High Performance Computer and Communications (HPCC), an Advanced Technology Initiative (ATI) will identify and invest in critical instrument, spacecraft, and information system technologies. This budget increases emphasis on a viable Applications, Commercial, and Education program that bridges the focused Research and Analysis and mission science investments with the Applications and Commercial Remote Sensing Program towards addressing key environmental problems of societal relevance. NASA also funds a $35.25 million program of weather-related research for aviation safety.

NUCLEAR REGULATORY COMMISSION (NRC)

The NRC requested funding is for meteorological operations. The FY 2001 request for $117,000 is reduced from the FY 2000 request, reflecting the expectation that work on RASCAL v3.0 will be completed in the third quarter of FY 2000.

The meteorological support program in the NRC is focused primarily on obtaining and analyzing meteorological data and information to be utilized in atmospheric transport and dispersion models used in dose projections, plume pathway characterizations, and concentration estimates related to the safe operation of nuclear facilities and the protection of public health and safety and the environment. Obtaining current, accurate, and relevant meteorological information on a real-time basis for use during emergencies is the primary consideration. In addition, the data may be used to provide input to the assessment of the radiological impacts of routine airborne releases from facilities and the assessment of the potential radiological impacts of engineering changes in plant design or operation proposed by licensees should unplanned releases occur. The NRC also maintains an interest in the transport and dispersion of airborne, hazardous non-radioactive materials and their potential effects on the safe operation of nuclear facilities.

AGENCY FUNDING BY BUDGET CATEGORY

Table 2.2 depicts how the agencies plan to obligate their funds for meteorological operations broken down by "budget category." The two major categories are "Operations Support" and "Systems Acquisition." To a large degree, these categories correspond to non-hardware costs (Operations Support) and hardware costs (Systems Acquisition). For agency convenience in identifying small components that do not fit into these two major categories, a third category is added called "Special Programs." Programs that provide support to several government agencies such as the Air Force's DMSP are listed on a separate line.

Table 2.3 describes how the agencies plan to obligate their funds for meteorological supporting research according to budget categories. The agencies' supporting research budgets are subdivided along similar lines--Research and Development (non-hardware), Systems Development (hardware), and Special Programs (for those items that do not easily fit into the two major categories).

AGENCY FUNDING BY SERVICE CATEGORY

Table 2.4 summarizes how the agencies plan to obligate operational funds for basic and specialized meteorological services; Table 2.5 is a similar breakout for supporting research funds. Table 2.4 reveals the distribution of operational funds: basic meteorology services receiving 58.2 percent; aviation, marine, general military services accounting for 30.6 percent, 3.2 percent, and 6.9 percent, respectively; and other specialized services and agriculture/forestry each receiving 0.6 percent. Table 2.5 shows the distribution of supporting research funds among the services with aviation meteorology receiving 23 percent, basic meteorology receiving 19.1 percent, marine and general military meteorology receiving about 7 percent, agriculture and forestry meteorology receiving 3.6 percent, and the remaining 39.4 percent dedicated to other meteorological services.

The definitions of specialized and basic services are described below:

Basic Services

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

Specialized Meteorological Services

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

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

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

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

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

TABLE 2.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Operations Support FY2000	Operations Support FY2001	Systems Acquisition FY2000	Systems Acquisition FY2001	Special Programs FY2000	Special Programs FY2001	Total FY2000	Total FY2001	Total % CHG	% of FY2001 TOTAL
Agriculture	12600	12600	0	0	0	0	12600	12600	0.0	0.6
Commerce/NOAA(Subtot)	644761	675503	579948	655144	18412	18754	1243121	1349401	8.5	60.2
NWS	523352	550005	124092	150701	9498	12526	656942	713232	8.6	31.8
NESDIS	102316	103303	455856	504443	6950	4898	565122	612644	8.4	27.3
OAR	3000	3152	0	0	0	0	3000	3152	5.1	0.1
NOS	9470	12175	0	0	1070	775	10540	12950	22.9	0.6
NOAA Corps	6623	6868	0	0	894	555	7517	7423	-1.3	0.3
Defense(Subtot)	273676	278867.8	109866	161046	636	696	384178	440609.8	14.7	19.7
Air Force	108473	116290	60760	68541	0	0	169233	184831	9.2	8.2
DMSP*	18171	13438	37598	68506	0	0	55769	81944	46.9	3.7
Navy	122651	123922	838	875	0	0	123489	124797	1.1	5.6
Army	24381	25217.8	10670	23124	636	696	35687	49037.8	37.4	2.2
Interior/BLM	940	940	160	160	0	0	1100	1100	0.0	0.0
Transportation(Subtot)	298732.6	306075.1	111656	122549	6460.5	4618.1	416849.1	433242.2	3.9	19.3
CG	6000	6000	0	0	0	0	6000	6000	0.0	0.3
FAA	292732.6	300075.1	111656	122549	6460.5	4618.1	410849.1	427242.2	4.0	19.1
FHWA					------ Not Applicable ------					
EPA					------ Not Applicable ------					
NASA	3238	2675	650	1285	0	0	3888	3960	1.9	0.2
NRC	180	117	0	0	0	0	180	117	-35.0	0.0
TOTAL	1234127.6	1276777.9	802280	940184	25508.5	24068.1	2061916.1	2241030	8.7	100.0
% of FY TOTAL	59.9%	57.0%	38.9%	42.0%	1.2%	1.1%	100.0%	100.0%		

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

TABLE 2.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Research & Development		Systems Development		Special Programs		Total			% of FY2001 TOTAL
	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	%CHG	
Agriculture	15500	15500	0	0	0	0	15500	15500	0.0	3.6
Commerce/NOAA(Subtot)	63190	61774	9563	12970	15767	17855	88520	92599	4.6	21.2
NWS	11883	11954	7700	11100	0	0	19583	23054	17.7	5.3
NESDIS	10319	11585	0	0	0	0	10319	11585	12.3	2.7
OAR	40988	38235	1863	1870	4333	4350	47184	44455	-5.8	10.2
NOS	0	0	0	0	10540	12950	10540	12950	0.0	3.0
NOAA Corps	0	0	0	0	894	555	894	555	-37.9	0.1
Defense(Subtot)	91036	90005.1	410	400	100	100	91546	90505.1	-1.1	20.8
Air Force	35714	33184	0	0	0	0	35714	33184	-7.1	7.6
DMSP*	21207	25372	0	0	0	0	21207	25372	19.6	5.8
Navy	18457	18706	0	0	0	0	18457	18706	1.3	4.3
Army	15658	12743.1	410	400	100	100	16168	13243.1	-18.1	3.0
Interior/BLM	------ Not Applicable ------									
Transportation(Subtot)	25452.9	32241.8	0	0	109	100	25561.9	32341.8	26.5	7.4
CG	------ Not Applicable ------									
FAA	22536.9	30341.8	0	0	0	0	22536.9	30341.8	34.6	7.0
FHWA	2916	1900	0	0	109	100	3025	2000	-33.9	0.5
EPA	6400	6400	0	0	0	0	6400	6400	0.0	1.5
NASA	118300	119800	53700	43600	35250	35250	207250	198650	-4.1	45.6
NRC	------ Not Applicable ------									
TOTAL	319878.9	325720.9	63673	56970	51226	53305	434777.9	435995.9	0.3	100.0
% of FY TOTAL	73.6%	74.7%	14.6%	13.1%	11.8%	12.2%	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.

TABLE 2.4 AGENCY OPERATIONAL COSTS, BY SERVICE

(Thousands of Dollars)

AGENCY	Basic Meteorology		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001
Agriculture	0	0	0	0	0	0	12600	12600	0	0	0	0	12600	12600
Commerce/NOAA(Subtot)	1177870	1281453	35461	35596	26790	29200	0	0	0	0	3000	3152	1243121	1349401
NWS	605231	661386	35461	35596	16250	16250	0	0	0	0	0	0	656942	713232
NESDIS	565122	612644	0	0	0	0	0	0	0	0	0	0	565122	612644
OAR	0	0	0	0	0	0	0	0	0	0	3000	3152	3000	3152
NOS	0	0	0	0	10540	12950	0	0	0	0	0	0	10540	12950
NOAA Corps	7517	7423	0	0	0	0	0	0	0	0	0	0	7517	7423
Defense(Subtot)	21346	21590	206350	222438	35659	36066	0	0	114183	153902	6640	6614	384178	440609.8
Air Force	0	0	169233	184831	0	0	0	0	0	0	0	0	169233	184831
DMSP*	0	0	0	0	0	0	0	0	55769	81944	0	0	55769	81944
Navy	21346	21590	36647	37065	35659	36066	0	0	23197	23462	6640	6614	123489	124797
Army	0	0	470	542	0	0	0	0	35217	48495.8	0	0	35687	49037.8
Interior/BLM	0	0	0	0	0	0	1100	1100	0	0	0	0	1100	1100
Transportation(Subtot)	0	0	410849	427242	6000	6000	0	0	0	0	0	0	416849.1	433242.2
CG	0	0	0	0	6000	6000	0	0	0	0	0	0	6000	6000
FAA	0	0	410849	427242	0	0	0	0	0	0	0	0	410849.1	427242.2
FHWA							------ Not Applicable ------							
EPA							------ Not Applicable ------							
NASA	0	0	0	0	0	0	0	0	0	0	3888	3960	3888	3960
NRC	180	117	0	0	0	0	0	0	0	0	0	0	180	117
TOTAL	1199396	1303160	652660	685276	68449	71266	13700	13700	114183	153902	13528	13726	2061916.1	2241030
% of FY TOTAL	58.2%	58.2%	31.7%	30.6%	3.3%	3.2%	0.7%	0.6%	5.5%	6.9%	0.7%	0.6%	100.0%	100.0%

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

TABLE 2.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE

(Thousands of Dollars)

AGENCY	Basic Meteorology		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001	FY2000	FY2001
Agriculture	0	0	0	0	0	0	15500	15500	0	0	0	0	15500	15500
Commerce/NOAA(Subtot)	76355	78024	1625	1625	10540	12950	0	0	0	0	0	0	88520	92599
NWS	19583	23054	0	0	0	0	0	0	0	0	0	0	19583	23054
NESDIS	10319	11585	0	0	0	0	0	0	0	0	0	0	10319	11585
OAR	45559	42830	1625	1625	0	0	0	0	0	0	0	0	47184	44455
NOS	0	0	0	0	10540	12950	0	0	0	0	0	0	10540	12950
NOAA Corps	894	555	0	0	0	0	0	0	0	0	0	0	894	555
Defense(Subtot)	5534	5419	35784	33254	18457	18706	0	0	31371	33026.1	400	100	91546	90505.1
Air Force	0	0	35714	33184	0	0	0	0	0	0	0	0	35714	33184
DMSP*	0	0	0	0	0	0	0	0	21207	25372	0	0	21207	25372
Navy	0	0	0	0	18457	18706	0	0	0	0	0	0	18457	18706
Army	5534	5419	70	70	0	0	0	0	10164	7654.1	400	100	16168	13243.1
Interior/BLM	------ Not Applicable ------													
Transportation(Subtot)	0	0	22536.9	30341.8	0	0	0	0	0	0	3025	2000	25561.9	32341.8
CG	------ Not Applicable ------													
FAA	0	0	22536.9	30341.8	0	0	0	0	0	0	0	0	22536.9	30341.8
FHWA	0	0	0	0	0	0	0	0	0	0	3025	2000	3025	2000
EPA	0	0	0	0	0	0	0	0	0	0	6400	6400	6400	6400
NASA	0	0	35250	35250	0	0	0	0	0	0	172000	163400	207250	198650
NRC	------ Not Applicable ------													
TOTAL	81889	83443	95195.9	100471	28997	31656	15500	15500	31371	33026.1	181825	171900	434777.9	435995.9
% of FY TOTAL	18.8%	19.1%	21.9%	23.0%	6.7%	7.3%	3.6%	3.6%	7.2%	7.6%	41.8%	39.4%	100.0%	100.0%

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

PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 2.6 depicts agency staff resources in meteorological operations. The total agency staff resources requested for FY 2001 is 14,492. This total represents a decrease of less than 1 percent from FY 2001.

TABLE 2.6 PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS
(Units are Full Time Equivalent Staff Years)*

AGENCY	FY 2000	FY 2001	% CHANGE	% of FY 2001 TOTAL
Agriculture	104	104	0.0	0.7
Commerce/NOAA	5,708	5,696	-0.2	39.3
Defense(Subtotal)	5,103	5,086	-0.3	35.1
Air Force	3,316	3,334	0.5	23.0
DMSP	65	66	1.5	0.5
Navy	1,462	1,423	-2.7	9.8
Army	260	263	1.1	1.8
Interior/BLM	8	8	0.0	0.1
Reimbursed**	4	4	0.0	0.0
Transportation (Subtotal)	3,575	3,593	0.5	24.8
CG	85	85	0.0	0.6
FAA	3,489	3,506	0.5	24.2
FHWA	1	2	50.0	0.0
EPA	0	0	0.0	0.0
NASA	0	0	0.0	0.0
NRC	1	1	0.0	0.0
TOTAL	14,503	14,492	-0.1	100.0

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

INTERAGENCY FUND TRANSFERS

Table 2.7 summarizes the reimbursement of funds from one agency to another during FY 2000. Agencies routinely enter into reimbursable agreements when they determine that one agency can provide the service more efficiently and effectively than the other. While specific amounts may vary from year-to-year, the pattern shown is essentially stable and reflects a significant level of interagency cooperation.

Department of Commerce. NWS will reimburse DOT $2,500 for Alaska housing utilities. NASA will receive $60,000 for stratospheric studies. NESDIS will transfer a total of $384.6 million to NASA for procurement and launches of polar-orbiting ($98.2 million) and geostationary ($250.4 million) satellites.

Department of Defense. The Air Force will reimburse DOC a total of $787,000 for COMET participation ($372,000), OFCM support ($140,000), and Share Processing Network ($275,000); DOE ($65,000) for Argonne Laboratories supporting research; and NSF ($250,000) for NCAR supporting research. The Navy will reimburse DOC $218,000 for basic climatological analysis and forecasting, and interagency coordination. The Army reimbursements to DOC/NOAA include $571,000 to NWS for maintaining precipitation reporting stations and $260,000 to NOAA laboratories for precipitation modeling and basic research. The Army will also reimburse the AF Air Combat Command $100,000 for maintenance of weather systems. Finally, the United States Geological Survey will be reimbursed $770,000 for operations and maintenance of hydrologic and precipitation reporting stations.

Department of Transportation. The FAA will reimburse NOAA almost $19.0 million in FY 2001. Included in those funds are operational support associated with the WSR-88D and ASOS maintenance, the Center Weather Service Units at all Air Route Traffic Control Centers, the World Area Forecast System, for meteorology instructors at the FAA, and for studies and OFCM support.

The FAA will reimburse Army a total of $93,000 for supporting research. The NOAA will receive $2.2 million for various supporting research associated with aeronautical hazards mitigation. The NASA will receive $80,000 for supporting research.

National Aeronautics and Space Administration (NASA). The Air Force will receive reimbursement of $1.875 million for surface observations/forecasts and replacement of upper air systems. NOAA's NWS will receive $12,000 for an upper air analysis; and the National Data Buoy Center will receive reimbursements of $120,000 for the operation of two data buoys.

Environmental Protection Agency (EPA). NOAA's Air Resources Laboratory (ARL) will receive $5.4 million for development, evaluation, and application of air quality dispersion models; and for provision of meteorological expertise and guidance for EPA policy development activities.

Nuclear Regulatory Commission (NRC). The NRC will reimburse DOE $87,000 for technical assistance.

FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

Table 2.8 indicates the number of facilities/locations or platforms at which the federal agencies carry out (or supervise) the taking of various types of meteorological observations.

TABLE 2.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Agency Funds Transferred from:	Agency Funds Transferred to:	FY 2000 Funds ($K) Estimated or Planned Operations	Supporting Research
Commerce/NOAA	DOT/USCG	2.5	
	NASA Studies	60	
	NASA	348.6	
Defense/Air Force	DOC/NOAA/OFCM	140	
	DOC/SPN	275	
	DOC/COMET		372
	DOE/Argonne		65
	NSF/NCAR		250
Defense/Navy	DOC/NOAA/NCDC	58	
	DOC/NOAA/OFCM	160	
Defense/Army	DOC/NOAA/NWS	571	
	DOC/NOAA/ETL		65
	DOC/NOAA/ATDD		75
	DOC/NOAA		120
	DOI/USGS	770	
	DOD/ACC	100	
Transportation/FAA	DOC/NOAA	18,952	2,200
	DOD/USA		93
	NASA		80
NASA			
	DOD/USAF	1,875	750
	DOC/NOAA/NDBC	120	
	DOC/NOAA/NWS		12
EPA	DOC/NOAA/ARL		5,400
NRC	DOE/PNNL	87	

TABLE 2.8 FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

TYPE OF OBSERVATION/AGENCY	No. of Locations (FY 2000)
Surface, land	
Commerce (all types)	841
Air Force (U.S. & Overseas)	130
Navy (U.S. & Overseas)	34
Army (U.S. & Overseas)	39
Marine Corps (U.S. & Overseas)	13
Transportation (Flight Service Stn)	61
Transportation (Lim Aviation Wx Rptg Stn)	114
Transportation (Contract Wx Obsg Stn)	284
Transportation (Auto Wx Obsg Stn)	482
Transportation (Auto Sfc Obsg Sys, fielded)	570
Transportation (USCG Coastal	100
Interior	470
Agriculture	1080
NASA	3
Surface, marine	
Commerce (SEAS-equipped ships)	140
Commerce (Coastal-Marine Autom Network)	65
Commerce (NOAA/NOS/PORTS)	6
Commerce (Buoys--moored)	64
Commerce (Buoys--drifting)	21
Commerce (Buoys--large navigation)	10
Commerce (Water-level gauges)	189
Navy (Ships with met personnel)	29
Navy (Ships without met personnel	286
Transportation (USCG Ships)	70
NASA	2
Upper air, balloon	
Commerce (U.S.)	86
Commerce (Foreign, Cooperative)	22
Air Force, Fixed (U.S. & Overseas)	12
Air Force, Mobile	15
Army, Fixed (U.S. & Overseas)	10
Army, Mobile	51
Navy, Fixed (U.S. & Overseas)	11
Navy, Mobile	47
Navy, Ships	29
Marine Corps, Mobile	14
NASA (U.S.)	2
Atmospheric Profilers	
Army	7
Upper air, rocket	
NASA	2
Army (U.S. & Overseas)	1
Doppler weather radar (WSR-88D) sites	
Commerce (NWS)	123
Air Force (U.S. & Overseas)	29
Army (U.S. & Overseas)	3
Transportation	12
Doppler weather radar (Not WSR-88D) sites	
Air Force (Transportable)	4
Navy (Fixed)	9
Marine Corps (Mobile)	14
Off-site WSR-88D Processors (PUPs)	
Commerce (NWS)	63
Air Force	140
Navy	23
Army	9
Marine Corps	9
Transportation	25
NASA	2
Airport terminal Doppler weather radars	
Transportation (Commissioned)	41
Army (not airfield--Test Range/USAREUR)	2
Conventional radar (non-Doppler) sites	
Commerce (NWS)	31
Commerce (at FAA sites)	27
Air Force, Fixed (U.S. & Overseas)	7
Air Force, Remote Displays	2
Air Force, Mobile Units	3
Marine Corps, Mobile units	15
Weather reconnaissance (No. of aircraft)	
Commerce (NOAA)	3
Air Force Reserve Command (AFRC)	10
Geostationary meteorological satellites (No. operating)	
Commerce (planned config of 2)	2
Army (U.S. & Overseas)	1
Polar meteorological satellites (No. operating)	
Commerce (planned config of 2)	2
Air Force	4
Army (U.S. & Overseas)	1
Navy	(1 in orbit, status TBD)

DEPARTMENT OF COMMERCE WEATHER PROGRAMS
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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

NATIONAL WEATHER SERVICE

The National Weather Service (NWS) has the principal responsibility for the plans and operations of the basic weather, hydrologic and climate services and certain specific applied services. The NWS mission is to provide weather, water and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas to help protect life and property and enhance the national economy. NWS data and products form a national information data base and infrastructure which can be used by other governmental agencies, the private sector, the public and the global community. 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, climate, and oceanic service systems.
- Performs applied meteorological, hydrological, and climate research.
- Assists in developing community awareness and educational materials and programs concerning weather-related natural disasters.
- Participates in international hydrometeorological activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

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

- Organic Act of 1890 created the United States Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the United States 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" in the newly created Environmental Science Services Administration (ESSA).
- Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).

SERVICES

NWS provides around-the-clock weather and flood warning and forecast services. The NWS provides services through a national network of 121 Weather Forecast Offices (WFOs) and 13 River Forecast Centers (RFCs) (Figure 3-DOC-1) that collect data, prepare state and local warnings and forecasts, and disseminate information to the population both directly and indirectly through the mass media. In preparing local warnings and forecasts, WFOs use value-added forecast guidance prepared by the nine National Centers for Environmental Prediction (NCEP) (Figure 3-DOC-2). The core mission of the NWS also depends on the study, development, and testing of new methods for improving basic warning and forecast capabilities through research.

Weather Warnings and Forecasts. NWS forecasters at WFOs issue local warnings for severe weather such as tornadoes, severe thunderstorms, floods, and extreme winter weather. WFOs prepare forecasts for zones which are comprised of several counties that experience similar weather. Each WFO has forecast responsibility for several zones. WFOs also provide the main field forecast support for the marine and aviation programs as well as guidance for the fire weather program supporting federal lands management and wildfire control.

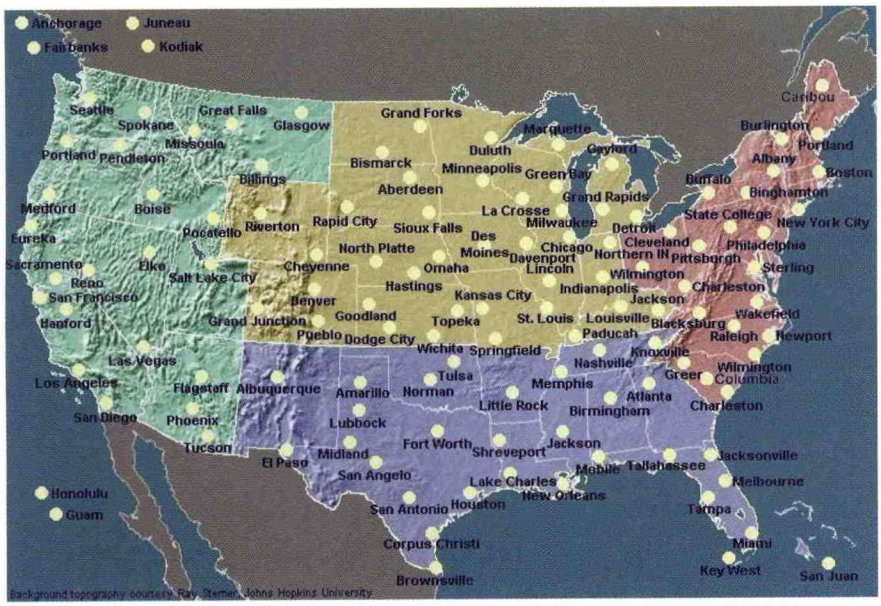


Figure 3-DOC-1. Locations of NWS Weather Forecast Office

Aviation Weather Services. The NWS provides a broad range of services in support of the aviation community. The WFOs prepare terminal airport forecasts four times a day with amendments as needed for over 500 public-use airports in the United States and in the Caribbean. These offices also produce about 300 individual route-oriented forecasts three times a day for the 48 contiguous states.

NCEP's Aviation Weather Center (AWC) and the Alaska Region's Aviation Weather Unit prepare area forecasts three times daily describing general aviation weather conditions over the lower 48 states and Alaska, respectively. These two specialized aviation weather centers, along with WFOs in Hawaii and Guam, issue in-flight advisories of hazardous weather conditions associated with thunderstorms, icing, turbulence, and strong, low-level winds.

NWS Center Weather Service Units located in each of the 21 Federal Aviation Administration Air Route Traffic Control Centers provide direct meteorological support to en route centers, Terminal Radar Approach Controls, and airport towers.

The NWS provides a service to international aviation as one of the International Civil Aviation Organization's two World Area Forecast Centers. NCEP's Environmental Modeling Center supplies global gridded model data of temperature, winds, and humidity twice a day for flight levels from 5,000 feet to 45,000 feet. The AWC prepares forecasts of significant weather for approximately two-thirds of the globe four times a day for thunderstorms, tropical cyclones, severe squall lines, moderate or severe turbulence, moderate or severe icing, and cumulonimbus cloud associated with the above, from 25,000 to 63,000 feet. The forecast charts also include information on jet streams and tropopause heights. This information is transmitted over the International Satellite Communications System with coverage in the Americas, Caribbean, western portions of Europe, the Pacific, and eastern Asia.

Within the framework of the international airways volcano watch, the NWS, through NCEP, shares management responsibility with NOAA's National Environmental Satellite, Data and Information Service (NESDIS) for Volcanic Ash Advisory Centers in Alaska and Washington.

Marine Weather Services. Using NCEP weather analysis and forecast guidance, marine weather forecasters at coastal and Great Lakes WFOs issue wind, wave, weather, and ice warnings, forecasts, and other information for populations living along the coastal waters and the Great Lakes. Principal products include small craft and heavy surf advisories, coastal flood warnings, coastal waters forecasts, sea and swell forecasts, and special weather forecasts to aid in the containment and clean up of oil spills and other hazardous substances in the marine environment.

Fire Weather Services. NWS offices provide routine pre-suppression and wildfire weather support to federal and state land management agencies. Upon request, NWS provides site-specific forecasts for prescribed burns on federal lands. The NWS deploys a national cadre of specially-trained Incident Meteorologists (IMETs) to large wildfires and coordination centers for on-site weather support. IMETs use weather instrumentation, telecommunications, and display equipment to aid in on-site forecast preparation and briefings. NCEP's Storm Prediction Center provides daily fire weather guidance that highlights areas with high fire potential based on the state of the fuels (trees, brush, grasses), and critical weather parameters such as low relative humidity, strong winds, and dry lightning activity.

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 United States territories and states bordering on the Pacific Ocean and disseminate this information to WFOs, federal and state disaster agencies, military organizations, private broadcast media, and other facilities that warn the public.

National Centers for Environmental Prediction.

Over the last several decades, NWS has made major improvements in forecasting synoptic-scale (large-scale, slowly evolving) weather. Further improvements will be realized in the severe weather and flood warnings program as a result of improvements in higher resolution, centrally prepared weather guidance products out to Day 5, implementation of NWS systems upgrades, advanced observations from the planned geostationary and polar-orbiting satellites, and the development of mesoscale predictive techniques for NWS field operations. While the NWS field structure focuses more on warnings and short-range forecasts, NCEP serves a broader, national mission where national centers provide products based on output from numerical models, statistical adjustments to model fields, and value-added products prepared by national center forecasters. This NCEP product suite is transmitted to the WFOs in digital form, where forecasters use the products to prepare local forecasts.

NCEP is organized into seven science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models -- the basis for NWS predictions. NCEP provides an integrated suite of forecast guidance and specific forecast products from the short-term through seasonal and interannual time frames. Each service center depends on the observational infrastructure, the data assimilation systems, the numeric modeling function, and the application of model output statistics to produce value-added forecast guidance products for NWS field offices and other users.

Storm Prediction Center. The Storm Prediction Center (SPC) focuses on hazardous weather events such as severe thunderstorms, tornadoes, extreme winter weather, and fire weather with emphasis on the first few hours of the forecast period. Other products issued from the SPC give the WFOs specific guidance on the probability and intensity of severe weather occurrences for regional and local geographic scales. The SPC also issues national outlooks for severe weather out to two days.

Hydrometeorological Prediction Center. The Hydrometeorological Prediction Center (HPC) prepares quantitative precipitation forecasts (QPF) used by WFOs to develop local rainfall, snow, and ice forecasts and by the RFCs to develop local river and flood forecasts. The HPC provides special QPFs and coordinates with other federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of analyses and forecasts out to seven days of frontal systems, pressure patterns, temperature, and precipitation for use by WFOs and the private weather community.

Marine Prediction Center. The Marine Prediction Center (MPC) handles United States international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). This center provides one-stop-shopping for marine interests operating outside the domain of coastal WFOs. The MPC provides weather and sea state warnings and forecasts for the high seas of the Northern Hemisphere north of 30 degrees for planning and operational purposes. MPC warnings and products go directly to ships and are vital for the protection of life and property at sea.

The MPC also coordinates forecasts with WFOs with coastal responsibilities. Coastal WFOs have responsibility for local forecasts and warnings that go out to approximately 60 nautical miles; for the high seas beyond, the MPC has responsibility.

Tropical Prediction Center/National Hurricane Center. The NCEP experts in the area of tropical meteorology are concentrated in the Tropical Prediction Center (TPC)/National Hurricane Center (NHC). TPC/NHC services include advisories, watches, and warnings for tropical cyclones in the North Atlantic and eastern North Pacific Oceans, the Caribbean Sea, and the Gulf of Mexico, including the portions of the coastline threatened by such storms.

In addition, TPC forecasters provide marine analyses and forecast products for the same areas of responsibility. The TPC/NHC provides guidance,

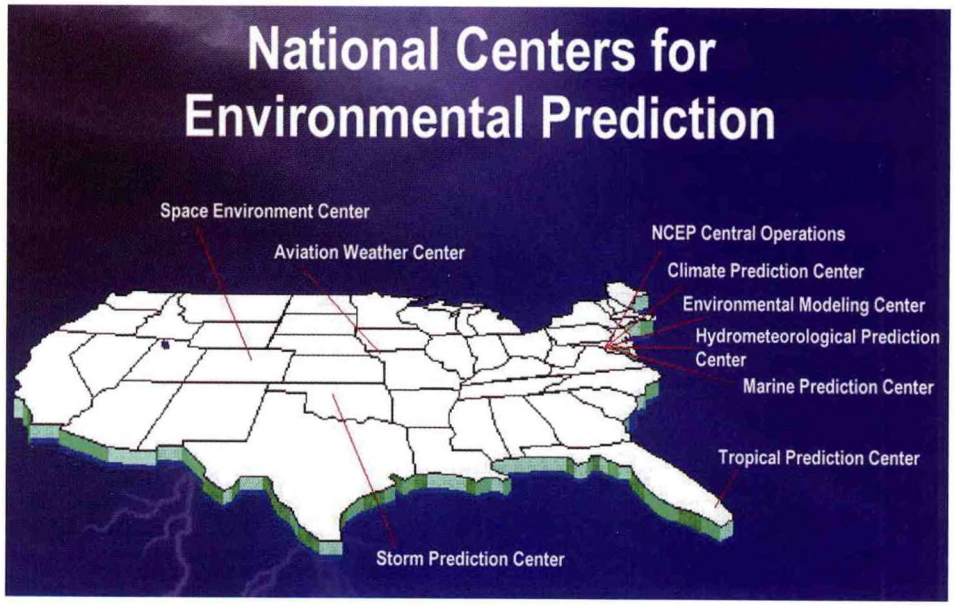


Figure 3-DOC-2. Locations of NCEP centers.

coordination, and tropical weather expertise to WFO forecasters, the media, and private industry.

Aviation Weather Center. The Aviation Weather Center (AWC) provides weather forecasts to the aviation community under an international agreement through the International Civil Aviation Organization. The AWC provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and en route aircraft operations for the United States, the Atlantic and Pacific routes in the Northern Hemisphere, and some routes in the Southern Hemisphere.

The AWC also produces guidance products used by WFOs to support airport terminal forecasts. Thus, the AWC produces large-scale, global aviation functions centrally, while the WFOs customize local aviation products based on centralized guidance provided by the AWC and local observations.

Climate Prediction Center. The Climate Prediction Center (CPC) produces services consisting of operational prediction of climate variability, monitoring of the climate system and development of data bases for determining current climate anomalies and trends, and analysis and assessment of their origins and linkages to the rest of the climate system. These services cover time scales ranging from weeks to seasons, and cover land, ocean, and atmosphere extending into the stratosphere. WFOs, as well as the public, private industry, and the international research community use CPC climate services.

Space Environment Center. The Space Environment Center (SEC) provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SEC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SEC issues specific predictions of the space weather activity level for the next three days and more general predictions up to several weeks in advance, as well as weekly summaries of observed solar-terrestrial conditions.

Environmental Modeling Center. The Environmental Modeling Center (EMC) improves NCEP's numerical weather, water, and climatic predictions through data assimilation and computer modeling. In support of the NCEP operational missions to provide ocean prediction, mesoscale prediction (thunderstorms, hurricanes, tornadoes, etc.), and global prediction, EMC develops, adapts, improves, and monitors data assimilation systems and models of the atmosphere, ocean, and atmosphere/ocean system. The EMC uses advanced modeling methods developed internally and cooperatively with universities, the international scientific community, NESDIS, NOAA laboratories, and other government agencies. The EMC integrates research and technology through collaborative model development projects. These interactions serve as an efficient and effective interface between NCEP and the scientific community that develops ideas, models, and techniques to improve NCEP products. The EMC also conducts applied research and technology transfers and publishes research results in various media for dissemination to the world meteorological, oceanographic, and climate community.

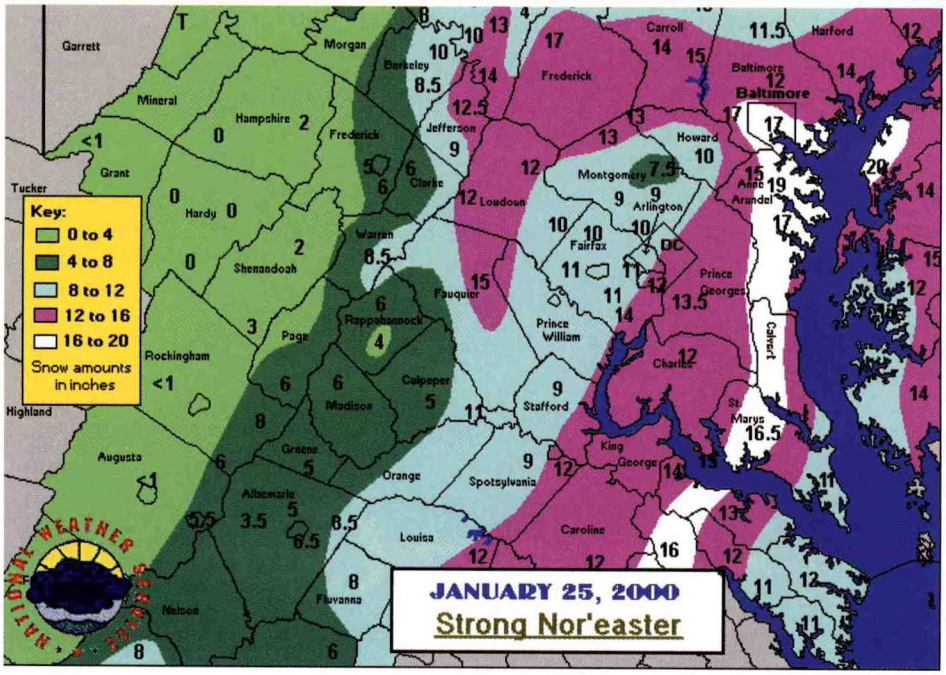
NCEP Central Operations. The NCEP Central Operations (NCO) is responsible for all aspects of NCEP operations, including access to real-time data, and its quality control and use in numerical weather prediction systems, as well as the workstations used by NCEP forecasters to access model output and other data necessary for producing guidance products. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications-related services that link individual NCEP activities together. The NCO is the focal point for establishing and executing policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO houses and runs the supercomputer facility that generates all NCEP model products. The NCO provides the technical transition between the research and development of numerical weather and climate prediction models and their operational use. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS mainframe and supercomputer systems, forecaster workstations, and personal computers.

SUPPORTING RESEARCH

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

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

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms).
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses.



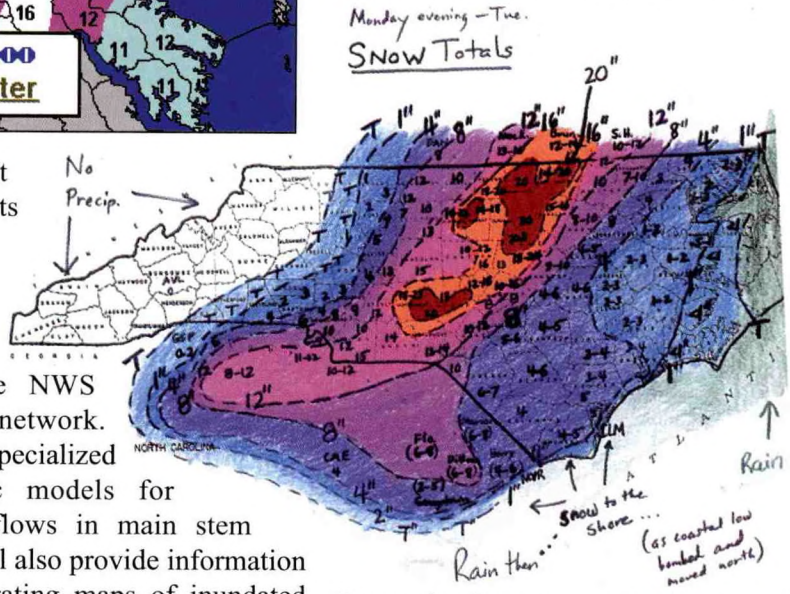


Figure 3-DOC-3. Quantitative Precipitation Forecast (above) compared with observed precipitation amounts (right).

- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.

Hydrologic Research. The NWS develops, implements, and operationally supports improved hydrologic, hydraulic, and hydrometeorological models and manages hydrologic data and enhanced quality control procedures to support national flood and water resources forecasting. Research encompasses the following areas:

- Improvements to the Ensemble Streamflow Prediction (ESP) system and its complimentary models in the NWS River Forecasting System. Research, development, and implementation of improved ESP procedures are a large component of the NWS' Advanced Hydrologic Prediction Services (AHPS) initiative.
- Specialized flood and flash flood forecasting procedures using linked hydrologic, hydraulic, and meteorological models. Major research areas include developing distributed hydrologic models that use high resolution precipitation data from the NWS radar network. Highly specialized hydraulic models for routing flows in main stem rivers will also provide information for generating maps of inundated areas.
- Development of improved multi-sensor precipitation estimates for input estimates for input into operational hydrologic and atmospheric models. Radar, rain gauge, and satellite rainfall estimates are merged to produce optimum rainfall analyses.

MODERNIZATION AND BEYOND

The NWS completed a modernization program in August 2000 that has ushered in a new era for severe weather and flood warning and forecast services. Important advances in the atmospheric sciences, coupled with major new technological capabilities for observing and analyzing the atmosphere, have provided unprecedented improvements in weather services. The NWS is operating and will continue to improve in the future, the most advanced hydrometeorological warning and forecast system in the world.

Through the WFOs, RFCs and NCEP, the NWS provides a uniform level of warning and forecast services nationwide. All of the new technologies have been deployed and are fully operational and include 314 Automated Surface Observing Systems, 123 Next Generation Weather Radars with Doppler capability, 154 Advanced Weather Interactive Processing Systems, geostationary and polar-orbiting satellites and a new supercomputer.

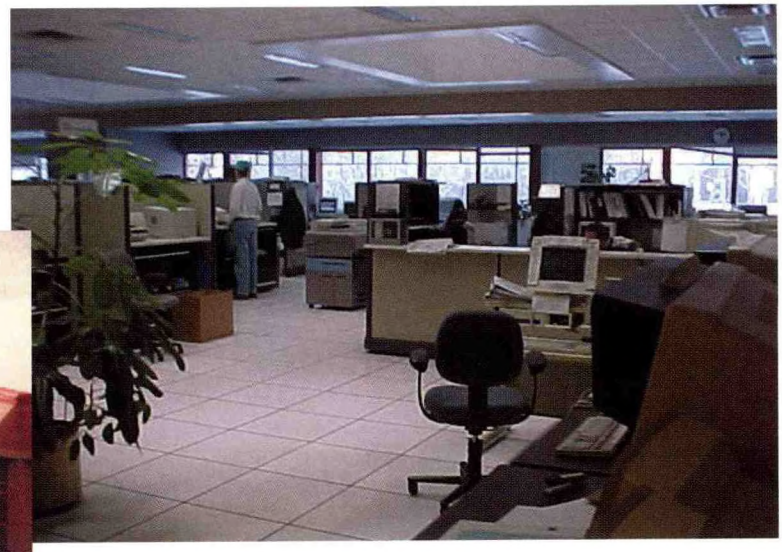
Statistics verify the substantial improvements in warning and forecast accuracy and timeliness. Advance warning for tornadoes has doubled and now averages 12 minutes. Advance warning for flash floods has nearly doubled. Accuracy of severe thunderstorm warnings has increased to 84 percent. The effectiveness of NWS modernization has been demonstrated during a number of major weather events during the past decade including: the March 1993 east coast blizzard, the January 1996 winter storm in the northeast, the January 1998 ice storm in New England, flooding events in the west in 1995 and 1997, tornado

outbreaks in the southeast in 1998, El Niño-related storms, floods and tornadoes during the winter of 1997-1998, and weather support during forest fires in the West throughout the summer of 2000.

With the completion of its decade-long modernization, NWS has a unique opportunity to capitalize on the extensive investments in science and technology to continue improving its services to the Nation. Emerging scientific and technological capabilities in weather, water and climate prediction are matched by increasing national needs for improved warnings and forecasts and a more integrated NWS focus in these three scientific disciplines. The NWS is now postured to blend forecasts in these areas into a seamless suite of products and services — accurate and timely products with high resolution and in a format that will provide users the flexibility to tailor the information to their specific needs.

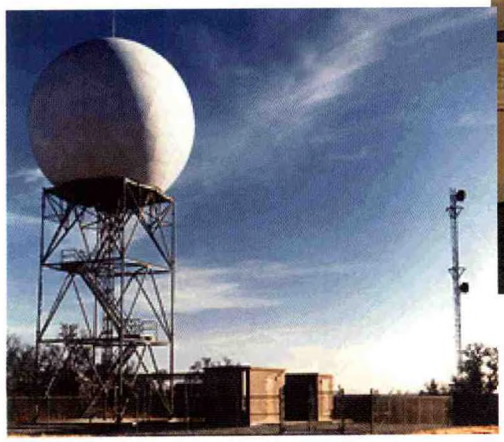
The characterization of a seamless suite of products and services means that by 2005 the NWS will provide weather, water, and climate forecasts for a specific geographic area from

Weather Forecast Office
Anchorage, Alaska



Weather Forecast Office
Atlanta, Georgia

Advanced Weather Interactive Processing System (AWIPS)



WSR-88D NEXRAD Weather Radar
Binghamton, New York

Figure 3-DOC-4. Modernized NWS offices and equipment.

time scales of minutes to seasons or years. Climate services will be provided months in advance to allow communities and businesses to prepare for extreme weather and water conditions. These will be further supported by forecasts that assess the threat of particular hazardous conditions (e.g., heavy precipitation or flooding) for specific areas of the country up to two weeks in advance. Finally, very precise forecasts of individual events (e.g., flash floods) will be provided hours and minutes in advance. In contrast, many of today's products and services are prepared independently of other products and services for the same geographic area. This results in potential inconsistencies and in less effective use of data and computational power. By 2005, NWS forecasts will be continuous, cumulative, consistent, relevant, and make the most effective use of data and computing power of the agency.

To achieve the above scenario of services by 2005, NWS has prepared a strategic plan for weather, water and climate services. The plan, published in August 1999, presents five goals:

- Deliver a credible, timely, and relevant suite of seamless weather, water, and climate products and services which exploit technology to the fullest to meet customer and partner needs;
- Aggressively and continually infuse science and technological advances to improve products and delivery of services that best meet and anticipate customer needs;
- Strengthen United States leadership on emerging application of weather, water, and climate information to meet environmental and economic challenges;
- Work with employees to create an organizational culture which embraces change; values service; promotes teamwork with customers, partners, and each other; and fosters innovation in mission and vision accomplishment; and
- Create a responsive support system, adaptable to changing needs and opportunities which maximize the return on investment to America.

The NWS focus through 2005 will be to harness an explosion of information technology, to strengthen linkages among the disciplines of weather, water, and climate prediction, to work more effectively with partners to improve and expand services, and to become a more responsive and efficient government agency.

The National Environmental Satellite, Data, and Information Service (NESDIS) manages United States civil operational environmental satellite systems, as well as global databases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. From these sources, NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and development and management of environmental resources (Figure 3-DOC-5).

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

NESDIS operates two primary polar-orbiting satellites in sun-synchronous orbits with equatorial crossing times in the early morning (circa 7:30 a.m. LST) and early afternoon (circa 1:40 p.m. LST). The orbits are circular, with an altitude between 830 km (morning orbit) and 870 km (afternoon orbit). These satellites orbit the Earth 14 times per day, collecting global data for atmospheric and surface measurements in support of short-term weather forecasting and longer-term global climate change research.

An agreement finalized with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) gives EUMETSAT responsibility for the morning segment of the polar environmental mission (circa 9:30 a.m. LST), with United States-provided payload instruments and sensors, beginning in 2003. Thus, upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission.

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

The IPO concept provides each of the participating agencies with lead responsibility for one of three primary functional areas. NOAA has overall responsibility for the converged system and is responsible to the IPO for satellite operations. NOAA is also the primary interface with the international and civil user communities. DOD is responsible to support the IPO for major systems acquisitions including launch support. NASA has a primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system. Although each agency provides certain key personnel in their lead role, each functional division is staffed by tri-agency work teams to maintain the integrated approach. The first converged satellite is expected to be available sometime toward the middle to latter half of this decade depending on when the current NOAA and DMSP programmed satellite assets are exhausted.

NPOESS will provide standard meteorological data, oceanographic, environmental, climatic, space environmental remote sensing information, as well as continuing to provide surface data collection and search and rescue capability. The IPO, in consultation with the NOAA and DMSP program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services.

NESDIS is also responsible for operating two Geostationary Operational Environmental Satellites (GOES). GOES-East stationed at 75°W monitors the Atlantic Ocean, the East and Gulf Coasts, and the Midwest; GOES-West at 135°W monitors the Pacific Ocean and West Coast. Due to an impending failure of the attitude and orbit control systems on GOES-9, it was replaced by GOES-10 in July 1998. GOES-11, the next in the series of GOES, was launched on May 3, 2000. It was placed in on-orbit standby at 104°W. It will replace either GOES-8 or GOES-10, when either satellite fails.

ENVIRONMENTAL SATELLITE SERVICES

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

OSO took over the command, control, and communications function of the DOD's Defense Meteorological Satellite Program (DMSP) constellation in 1998. The mission of DMSP is to provide meteorological and special sensor data to users in support of world wide DOD missions. DMSP is now operated from the SOCC at Suitland, Maryland. SOCC is the primary center for normal operations, mission planning, engineering, launch and early orbit support, and anomaly resolution.

A new ground system was developed for DMSP called Integrated Polar Acquisition and Control Subsystem.

The Office of Satellite Data Processing and Distribution (OSDPD) directs the operations of NESDIS central ground data processing facilities. It processes and distributes current weather satellite data and derived products to the NWS and other domestic and foreign users, and provides coordination and customer services for satellite direct readout and direct broadcast users. OSDPD distributes NOAA and non-NOAA environmental satellite products to the NWS National Centers and Weather Forecast Offices (WFOs), who provide further distribution to regional NWS offices and other federal, state, and private sector agencies. OSDPD is currently generating modern remapped digital data satellite products for further distribution via NOAAPORT, a satellite point-to-multi-point broadcast. NOAAPORT delivers various GOES products in virtually real-time to the Advanced Weather Interactive Processing Station (AWIPS). AWIPS, a new display and analysis workstation, enables NWS

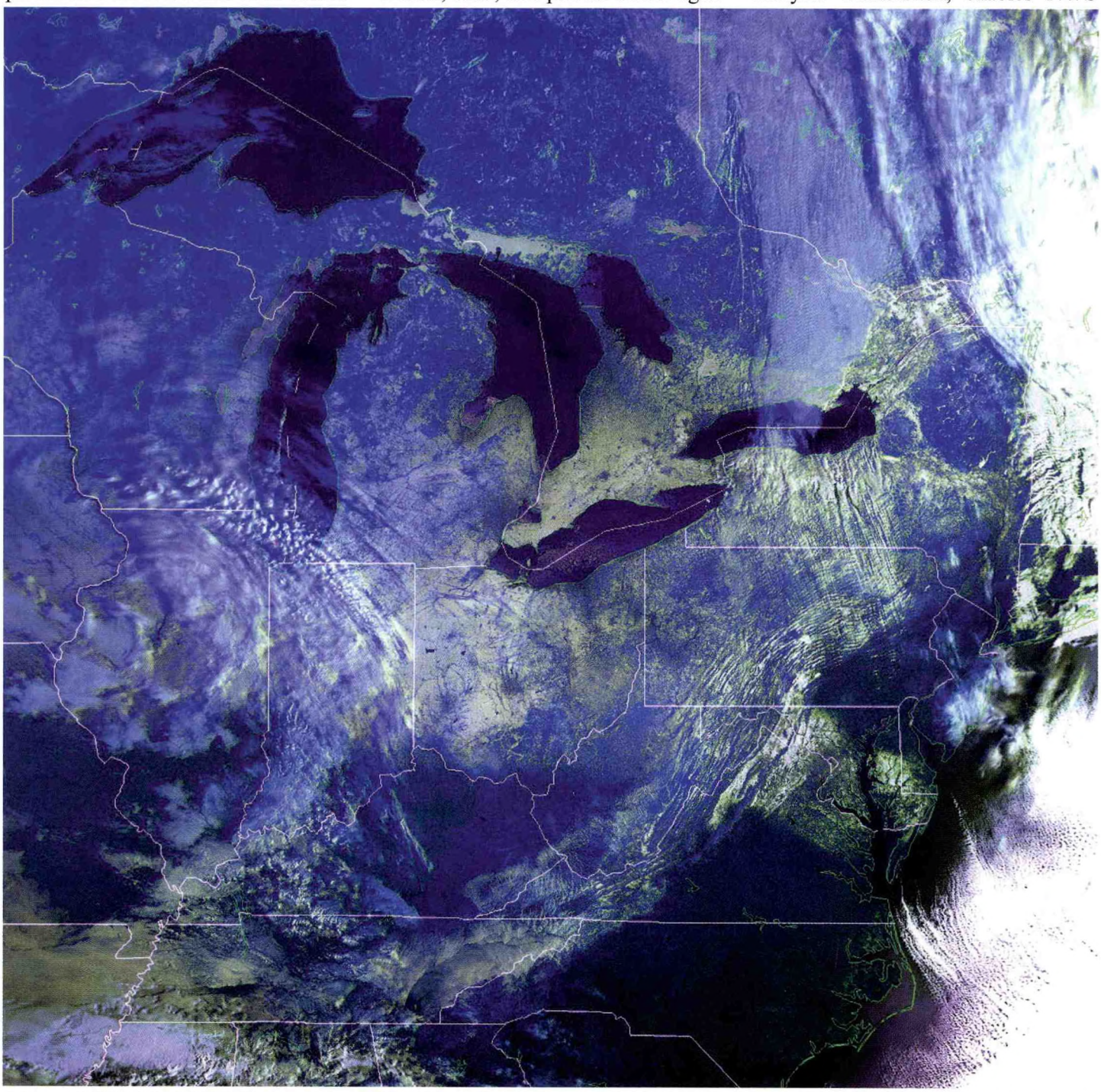


Figure 3-DOC-5. NESDIS Operational Significant Event Imagery (OSEI)--Snowstorm over Southeast United States on March 11, 1999

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

NESDIS continued its support of the COSPAS-SARSAT Program through provision of satellites, ground stations, and alert data distribution services. Russia, the United States, France, and Canada provide the space segment and related ground systems for COSPAS-SARSAT. NESDIS operates and maintains the United States SARSAT Mission Control Center and seven ground stations. The ground stations receive Doppler signals directly from the satellites and process the information to provide the location of distress transmissions. In 1999, COSPAS-SARSAT began to incorporate Geostationary Earth Orbit Search and Rescue (GEOSAR) satellite systems as a supplement to the existing COSPAS-SARSAT polar-orbiting system. GEOSAR systems provide instantaneous alerting capability and can significantly decrease rescue times. In 1998, the COSPAS-SARSAT Council also agreed to implement new emergency beacon location protocols to provide precise location within the beacon message using the United States Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS).

National Ice Center

The United States National Ice Center (NIC), under sponsorship of the United States Navy, NOAA, and the United States Coast Guard (USCG), is tasked with providing global sea ice and Great Lakes ice information in support of shipping, cryospheric research, and other maritime activities. NIC ice guidance products are produced in a digital workstation environment using data from polar orbiting satellites, ship/shore station reports, drifting buoys, meteorological guidance products, ice model predictions, and government partners including foreign ice services. The primary remotely sensed data sources used for global and regional-scale ice mapping are visible and infrared imagery from the TIROS-N Advanced Very High Resolution Radiometer (1.1km spatial resolution) and the DMSP Operational Linescan System (0.55km spatial resolution). In areas of extensive cloud cover, the NIC utilizes Special Sensor Microwave Imager (SSM/I) sensor data (19 and 37 GHz channels) processed using the CAL/VAL and NASA Team ice concentration algorithms (Figure 3-DOC-6). These algorithms produce 25km gridded mosaic ice maps that are instrumental in the production of NIC weekly composite Arctic/Antarctic ice maps. Higher resolution ice analysis products, used to ensure the safety of navigation and protect life and property at sea, are dependent upon the availability and use of Synthetic Aperture Radar (SAR) data from the Canadian RADARSAT. Of greatest utility to NIC is RADARSAT's ScanSAR Wide mode with a 500km wide swath and 100m spatial resolution. Images are processed at four Arctic ground stations and transferred to the NIC via dedicated communication lines or via the Internet within six hours of acquisition. The NIC Science team, which assists in the transition of pertinent scientific research to operations, is presently evaluating ARKTOS, an automated expert system that uses

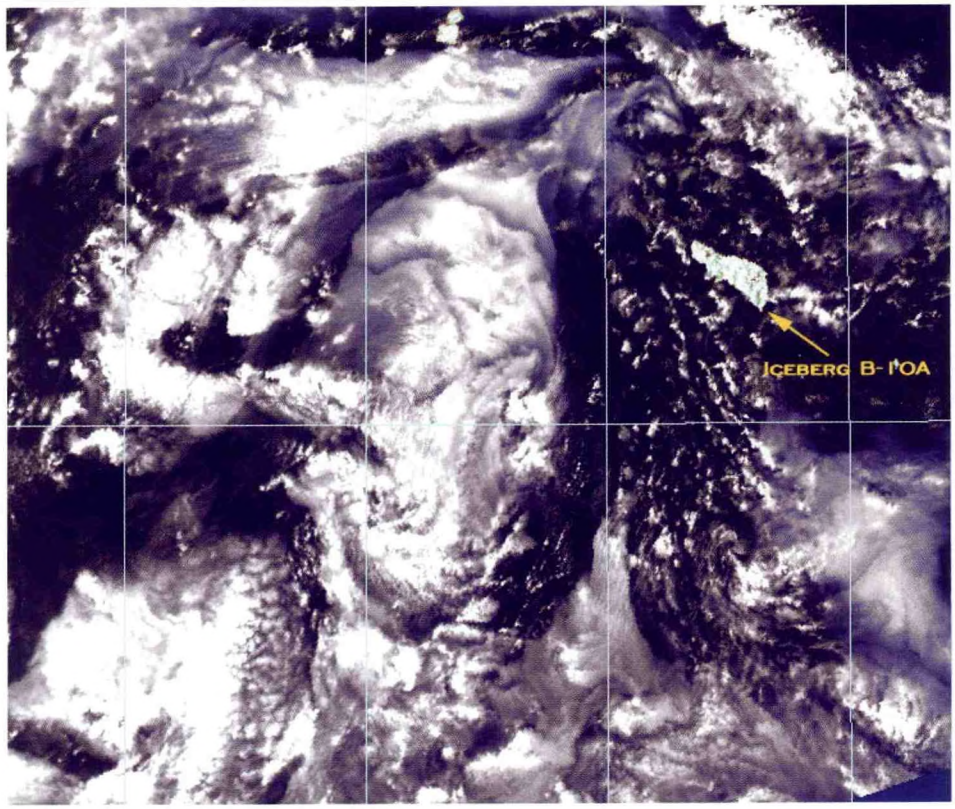


Figure 3-DOC-6. Iceberg B-10A is located amidst the cloud over in the Southern Ocean on January 9, 2000. Approximate location of the iceberg is 55.46S 37.35W.

knowledge-based rules to classify sea ice in RADARSAT SAR images.

Routine NIC ice guidance products include regional-scale ice maps, annotated satellite imagery, short and long-term ice forecasts, legacy ice information and ice climatology. NIC services available via special request include ship route recommendations, pre-sail ship briefings, aerial ice reconnaissance, and ship rider support. Sea ice features of most frequent interest include ice edge position, ice concentration, ice thickness, form or floe size, ice motion, areas of compression and heavy surface deformation, and the location/orientation of open water or thin ice-covered leads. Ice products are distributed via the Internet (*http://www.natice.noaa.gov*) as simple electronic charts in Graphics Interface Format (GIF), GIS-compatible coverages (ESRI ARC/INFO .e00 export format), and in the World Meteorological Organization (WMO) digital standard for Sea Ice in GRIDed (SIGRID, SIGRID-2) format. Date and time of data acquisition as well as the percentage of each data type used in all ice analyses are documented in a metadata narrative.

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

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

Polar-Orbiting Systems

The primary mission of the Polar-Orbiting Operational Environmental Satellite (POES) System is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the two primary operational spacecraft are NOAA-15 and NOAA-14.

NOAA polar satellites carry instruments to provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system, and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users. In addition to taking thermal images of the earth's surface and atmosphere, the NOAA polar-orbiting satellites carry sounder instruments to provide vertical profiles of atmospheric temperature and moisture.

POES satellites carry four primary instrument systems: the Advanced Very High Resolution Radiometer (AVHRR); the Television Infrared Observation System (TIROS) Operational Vertical Sounder (TOVS); the Space Environment Monitor (SEM); and the Solar Backscatter Ultra-Violet Instrument (SBUV/2). The AVHRR provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, and snow and ice mapping.

NOAA-15 carries the first of a new generation of imager and sounder. The AVHRR on NOAA-15 contains a switchable Channel 3A (1.6 microns (μm)) and Channel 3B (3.7μm). NOAA-15 also carries the first Advanced-TOVS, or ATOVS. ATOVS consists of the High Resolution Infrared Radiation Sounder (HIRS/3), the Advanced Microwave Sounding Unit-A (AMSU-A), and the Advance Microwave Sounding Unit-B (AMSU-B), replacing the Microwave Sounding Unit (MSU) and the Stratospheric Sounding Unit flying on older polar-orbiting satellites. The new AMSU instruments are designed to provide

increased accuracy in temperature and humidity retrievals.

The HIRS/3 is a discrete-stepping, linescan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from Earth's surface to about 40km. Multi-spectral data from one visible channel (0.69μm), seven shortwave channels (3.7 to 4.6μm), and twelve longwave channels (6.5 to 15μm) are obtained from a single telescope and rotating filter wheel containing twenty individual filters. An elliptical scan mirror provides cross-track scanning of 56 increments of 1.8μm. The mirror steps rapidly (<35 msec), then holds at each position while the 20 filter segments are sampled. This action takes place each 100 msec. The instantaneous field of vision (FOV) for each channel is approximately 1.4μm in the visible and shortwave IR, and 1.3μm in the longwave IR band which, from an altitude of 833km, encompasses an area of 20.3km and 18.9km in diameter, respectively, at nadir on the Earth.

Each AMSU-A instrument is composed of two separate units: (a) AMSU-A2 with two channels at 23.8 and 31.4GHz and (b) AMSU-A1 with twelve channels in the range of 50.3 to 57.3GHz and one channel at 89.0GHz. The AMSU-B has five channels with frequencies centered on 89, 150, 183±1, 183±3, and 183±7Ghz, respectively. AMSU-B, provided by the United Kingdom Meteorological Office, produces soundings of humidity from the surface to 200 millibars (mb). AMSU-A has a nominal FOV of 3.3 degrees (48km on surface at nadir) and AMSU-B a field of view of 1.1 degrees (16km on surface at nadir). AMSU-A (AMSU-B) samples 30 degrees (90) Earth views, covering ±48.95 degrees from the sub-satellite point. In addition, the specialized 89GHz channel, with the capability to "see" through high and mid-level clouds to low level moisture clouds, is utilized to determine the position and structure of tropical cyclones on a global scale. The AMSU-A1 uses two antenna systems, providing observations in the twelve oxygen band channels (3-14) for retrieving the atmospheric temperature profile from the Earth's surface to about 42km, or from 1000 to 2 mb. The remaining three channels (1 and 2 from A2 and 15 from A1) aid the retrieval of temperature soundings by correction of surface emissivity, atmospheric liquid water, and total precipitable water. These window channels also provide information on precipitation, sea ice, and snow coverage.

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

In addition to the three instrument systems previously described, the "afternoon" POES carry the SBUV/2. SBUV/2 is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth. The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems: the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental Satellite Computer System (CEMSCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, CDA stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland. PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDA's to Suitland is accomplished by using the General Electric American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops, and Fairbanks, delivers the data to SOCC. These data are immediately passed to the CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location, calibration, and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions which are disseminated to users throughout the world.

The POES Data Collection (and location) System (DCS) is provided through an international cooperative agreement with the Centre Nationale d'Etudes Spatiales of France and is called the ARGOS DCS. The system provides a means to locate and collect environmental data from fixed and moving platforms; i.e., polar ice flows, ocean buoys, oil pipelines, birds, mammals, etc. The ARGOS DCS supports environmental applications, e.g. meteorology, oceanography, and protection of the environment, with the majority of users being government/non-profit agencies and researchers. An instrument upgrade to incorporate a downlink message capability is planned for the NOAA-N' satellite.

Geostationary Satellite Program

Two operational geostationary satellites, GOES-8 (75°W) and GOES-10 (135°W), provide coverage of virtually the entire western hemisphere for oper-

ational meteorological services. The projected launch schedule and associated instruments for geostationary satellites are shown in Table 3.1.

The GOES satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9μm and 12.0μm wavelengths. However, beginning with GOES-M, the 12.0μm channel will be replaced with a 13.0μm channel, with the goal of achieving more accurate cloud height assignments for mid- and upper-level atmospheric wind-velocity estimates.

GOES satellites transmit all five spectral bands simultaneously, providing the user community with continuous views of atmospheric measurements in various wavelengths, each with its own meteorological and hydrological application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled. For example, the full-earth disk is normally scanned once every 3 hours and requires about 30 minutes to complete the entire scan. Depending on requirements to monitor environmental hazards on the Earth's surface or in the atmosphere, 30-minute periods in between the full-disk scans may be scheduled as a mixture of 15-minute intervals (routine operations) or 7½-minute interval (severe operations) scans over the contiguous United States. To further support mesoscale and microscale analyses, 1000 km x 1000 km areas can also be scanned at 1-minute intervals, to capture rapidly developing and dynamic environmental phenomena. The five channels and respective resolutions are as follows:

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

The GOES-8 and GOES-10 sounder instruments, consisting of 19 spectral channels, are used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Products derived from the sounder include precipitable water and lifted index - a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverages, such as full-Earth imagery, sectorized imagery, and local imagery. In routine operations, GOES-8 and GOES-10 provide hourly sounding coverage.

The GOES Space Environment Monitor (SEM) collects data for warnings of solar activity. This block of instruments is more extensive than on POES. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three-component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users on-line via Internet and on a variety of computer media.

GOES also carries a Data Collection System (DCS) which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide guages, seismometers, buoys, ships, and automatic weather stations. In support of NOAA missions, GOES DCS data are used in weather forecasts and warnings, reservoir control, and flood monitoring. While the GOES DCS is a critical element for national and international meteorological and hydrological programs, the NWS NEXRAD program relies on the DCS data as a vital input for calibration and validation. Tsunami watches and warnings for the Pacific Ocean are prepared using the Data Collection Platform data transmitted via GOES DCS. The GOES DCS program touches all aspects of our lives in supporting water quality, air pollution, and global environmental monitoring.

The GOES Search and Rescue Satellite Aided Tracking (SARSAT) System is capable of providing an immediate distress alert, unlike the POES satellite SARSAT transponders which must come within line of site of either of a Local User Terminal, in order to relay the distress beacon back to the United States SARSAT Mission Control Center (USMCC). Newer state-of-the art COSPAS-SARSAT distress beacons, utilizing the Global Positioning System (GPS), now have the capability to provide location information in the distress message relayed by GOES to the USMCC.

NESDIS continues to improve user access to its operational satellite products and services using new communications technologies including the Internet. One important on-line access system, managed and operated by OSDPD and NOAA's National Climatic Data Center (NCDC), is the NOAA Operational Satellite Active Archive (SAA). The SAA (*www.saa.noaa.gov*) provides satellite data access, display, and electronic transfer. Available data types include AVHRR, ATOVS, DMSP (special sensor), and RADARSAT (authorized subscription users). While developed as an independent system, the SAA serves as NOAA's initial interoperable interface to NASA's Earth Observing System Data and Information System (EOSDIS). After the phase-out of the GOES-TAP system in 1998, many users now rely on GOES sector images, mapped to standard AWIPS grids, available in near real-time, at *www.goes.noaa.gov*. Finally, special

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA L	CY 2000
NOAA M	CY 2001
METOP-1	CY 2003
NOAA-N	CY 2003
NOAA-N'	CY 2008
METOP-2	CY 2008
METOP-3	CY 2012
NPOESS-3	CY 2014
NPOESS-4	CY 2016
NPOESS-5	CY 2018

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES M	CY 2001
GOES N	CY 2002
GOES O	CY 2005
GOES P	CY 2007
GOES Q	CY 2010
GOES-R	CY 2012

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

NOAA Instruments for NOAA Polar-Orbiter and METOP Series

AVHRR - Advanced Very High Resolution Radiometer
SEM - Space Environment Monitor
SBUV - Solar Backscatter Ultraviolet Instrument (NOAA PM mission only)
HIRS - High Resolution Infrared Sounder
DCS ARGOS - Data Collection System
AMSU-A - Advanced Microwave Sounding Unit-A
AMSU-B - Advanced Microwave Sounding Unit-B
SARP - Search and Rescue Processor
SARR - Search and Rescue Repeater
MHS - Microwave Humidity Sounder (NOAA-N/N' and METOP)

Instruments for NPOESS Series

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

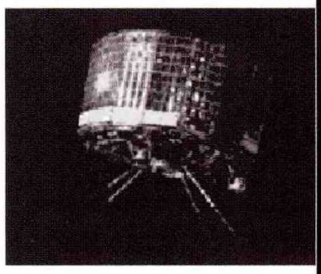
Instruments for GOES-Next Series

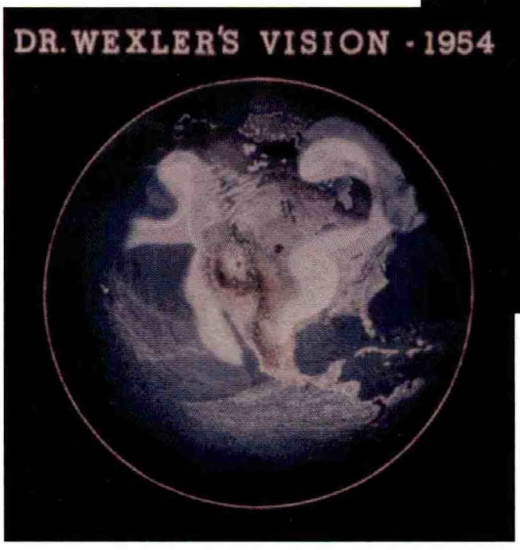
Imager
Sounder
SEM - Space Environment Monitor
SXI - Solar X-Ray Imager (GOES M and N)

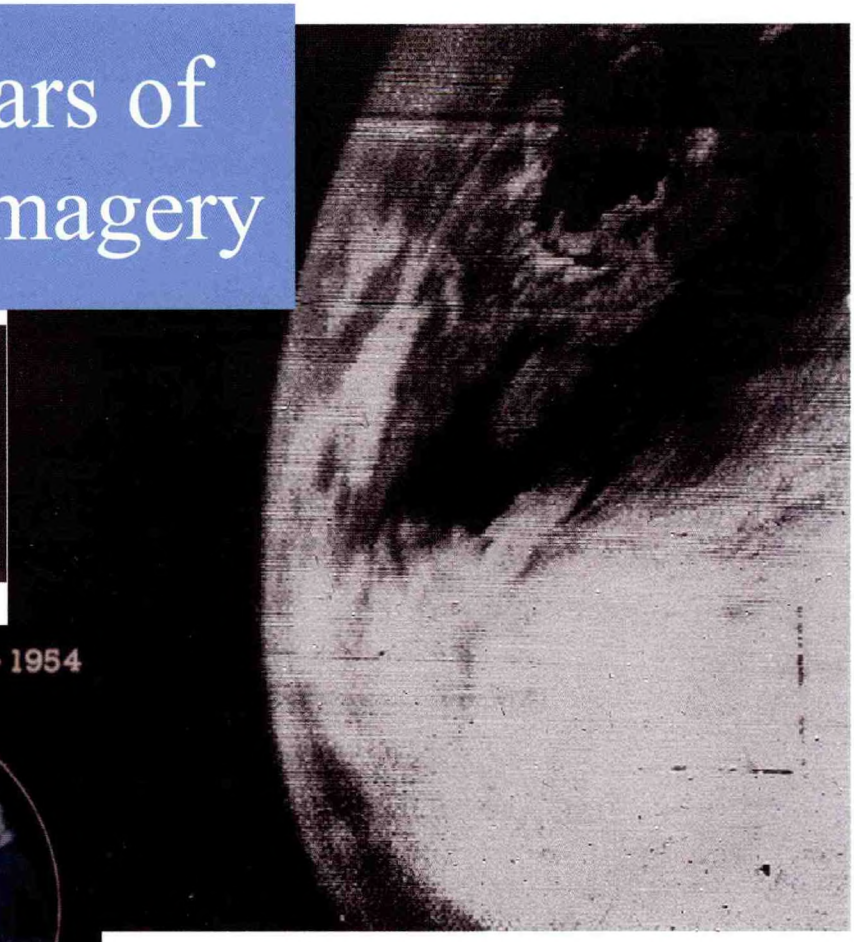
EUMETSAT Unique Instruments for METOP Series Satellites

ASCAT - Advanced Scatterometer
GOME - Global Ozone Monitoring Experiment
GRAS - GPS Receiver for Atmospheric Sounding
IASI - Infra-red Atmospheric Sounding Interferometer

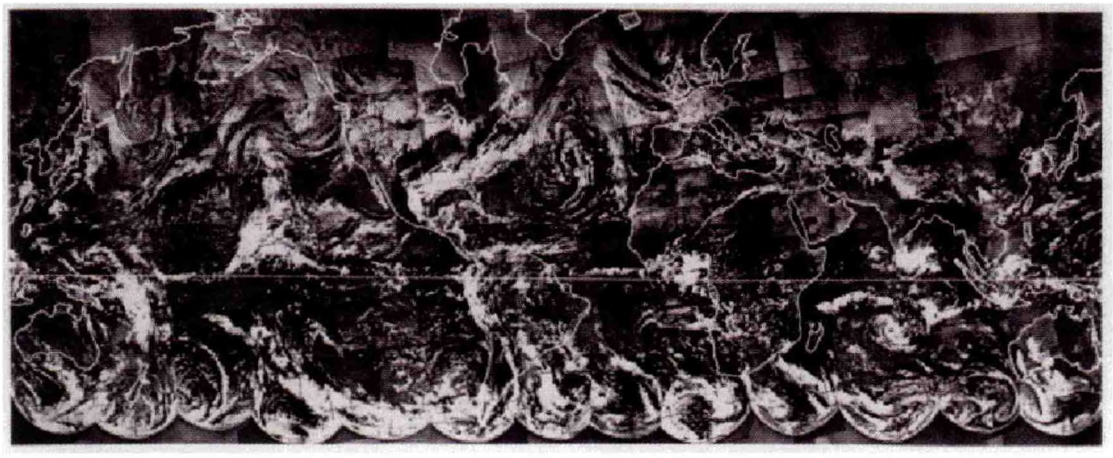
Forty years of Satellite Imagery







TIROS I on April 1, 1960
First TV image from space



First complete view of the world's weather by TIROS IX on February 13, 1965

events of natural disasters, including floods, hurricanes, other severe storms, volcanoes, and fires, specifically enhanced and annotated for use by the news media, federal, state, and international governments and agencies, are available from the Operational Significant Events Imagery (OSEI) server (*www.osei.noaa.gov*) (See Figure 3-DOC-5).

INTERNATIONAL SUPPORT FOR HAZARD MITIGATION

The Committee on Earth Observation Satellites (CEOS) was formed in 1984, in response to recommendations from the Economic Summit of Industrialized Nations Working Group on Growth, Technology, and Employment's Panel of Experts on Satellite Remote Sensing. This group recognized the multi-disciplinary nature of satellite-based Earth Observation (EO) data and the value of coordination across all proposed missions. In CEOS, providers and users of EO satellite data work together to promote the effective use of data from such satellites. Recognizing the benefits that could be gained from better application of EO satellite data to natural and technological hazards, CEOS initiated an activity on disaster management support. The Director of NESDIS/OSDPD chairs the group. The Disaster Management Support Group focuses on developing and refining recommendations for the application of satellite data to selected hazard areas. Particular emphasis is placed on working closely with space agencies, international and regional organizations, and commercial organizations on the implementation of these recommendations.

The Disaster Management Support Group began as a project in 1997 with an objective to support natural and technological disaster management on a worldwide basis by fostering improved utilization of existing and planned Earth observation satellite data. Meetings are held two to three times per year. Hazards addressed include drought, earthquake, fire, flooding, landslides, oil spill, sea ice, and volcanic hazards. Teams were charged with compiling user requirements; identifying shortcomings and gaps in the provision of required satellite data; and developing recommendations for alleviating them. Hazard team reports are included in the Group's annual progress reports. The latest annual progress report is available in hardcopy or via the group's web site (*disaster.ceos.org*).

SUPPORTING RESEARCH PROGRAMS

Recent advances in numerical weather prediction (NWP) models, both at NOAA's NCEP/EMC and other major International NWP Centers, require higher quality satellite derived winds, particularly over the traditionally data void oceanic regions of the globe. In 1998, NESDIS implemented an upgraded operational wind production suite which provides higher quality imager-based cloud-drift and water vapor motion winds at significantly increased spatial and temporal resolution. The system is totally automated and uses a series of geostationary satellite images to derive wind estimates. Automated quality control of image registration is an important component of the NESDIS GOES winds processing suite. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperature data to assign heights to these derived wind estimates. With increased computer resources, a ten-fold increase in the yield of "good" wind vectors for GOES-8 and GOES-10 are being generated every 3 hours for the Northern and Southern Hemisphere. Approximately 20,000 cloud-drift and water vapor motion wind vectors are derived from both satellites for each cycle and distributed to EMC and to the Global Telecommunications System (GTS). EMC uses these operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems. NESDIS recently completed the effort to reformat the winds in WMO-sanctioned BUFR format. Current work involves the investigation of a slow bias seen in water vapor winds.

The newest satellite wind products include the low level high density visible satellite winds. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower-tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low level flow in the outer storm vortex region which is an important area in assessing storm motion. The GOES satellites have an atmospheric sounder that includes two water vapor channels centered at 7.0μm and 7.3μm. These sounder channels can be employed as surrogate imagers to track water vapor features radiating from the lower layers of the troposphere. The weighting function of the 7.0μm channel peaks around 450mb and the weighting function of the 7.3μm channel peaks around 550mb. Water vapor winds generated from these two channels will compliment the imager-based cloud-drift and water vapor winds, resulting in an improved three-dimensional depiction of the wind field. The implementation of these new algorithms and the visible wind products into the operational environment at NESDIS began in 1999. These wind products can be viewed at *orbit-net.nesdis.noaa.gov/goes* and *cimss.ssec.wisc.edu/tropic/real-time.*

Atmospheric Moisture and Stability Products

Research continues to improve the atmospheric moisture and stability products from the GOES-8 and GOES-10 sounder instruments. Precipitable water for three layers of the atmosphere: surface to 900 hPa; 900-700 hPa; and 700-300 hPa are computed from the soundings. Total precipitable water (TPW) for the entire atmospheric column, from the earth's surface to the "top" of the atmosphere, is also computed. These precipitable water products are particularly valuable for the short-term forecasting of precipitation, locating those environments favorable for heavy precipitation and flash floods, thunderstorms, and fog. Hourly updates of this information provide useful information for the EMC regional data assimilation systems and for weather forecasters in the field. EMC currently uses the GOES precipitable water retrievals as input to ETA Data Assimilation System (EDAS) which provides the initialization for the ETA forecast model. NESDIS is currently aiding EMC with running global and regional model impact analyses to improve and optimize the use of the GOES derived products in numerical weather prediction schemes. At present, a blended GOES, SSM/I, and model-derived product is being evaluated. In addition, a precipitable water product has been developed from the NOAA-15 AMSU sensor, and is presently undergoing evaluation. In the near future, the blended product will include the AMSU-derived precipitable water. In addition to the moisture products, numerous atmospheric stability indices can be computed from measurements made by the GOES sounder instrument. Two stability indices, the lifted index (LI) and CAPE index, are computed on a routine basis. Since these indices are produced hourly, sequential images of these derived quantities clearly show the diurnal and dynamic changes associated with weather events. So, in addition to providing these data to EMC for use in numerical weather prediction models, the graphical representation of these products allows for the looping of the products in time. This capability aids NWS forecasters in the field, for example, to understand the time evolution of severe storms. It was anticipated that the GOES sounder moisture and stability products which presently have a horizontal resolution of approximately 50 km^2, would be generated at a high horizontal resolution of 30 km^2 by the summer of 2000. These products can be viewed at *orbit-net.nesdis.noaa.gov/goes* and *cimss.ssec.wisc.edu*. A similar suite of products is being developed from NOAA-14 and NOAA-15 for forecasters.

Precipitation Estimates

The Auto-Estimator produces quarter-hourly estimates of precipitation based on GOES infrared data. This technique was devised to replace the more manual "Interactive Flash Flood Analyzer" (IFFA). The Auto-Estimator has an orographic adjustment factor and can be manually adjusted for warm cloud tops. Current improvements being tested include using: RADAR and visible data (as a rain/no-rain detector) and equilibrium level temperatures from the ETA model for warm top adjustments. Other techniques are being tested such as the GOES Multi-Spectral Rainfall Algorithm (GMSRA), a combined GOES and SSM/I rainfall algorithm (developed at NRL/Monterey), and a NOAA-15 AMSU based retrieval algorithm. The GMSRA uses all five GOES imager channels and may be merged with the Auto-Estimator after the intercomparison is completed. Finally, the POES based microwave algorithms from the SSM/I and AMSU sensors are being utilized to produce automated tropical cyclone rainfall potential estimates and global precipitation estimates are produced from microwave data for climate monitoring and analysis. These products can be viewed at: *orbit-net.nesdis.noaa.gov/arad/ht* and *manati.wwb.noaa.gov/doc/ssmiprecip.html*

Microburst Products

Several experimental microburst and convective wind gust products are being tested. These products utilize sounder data from both GOES-East/West to compute the maximum possible wind gust and the potential for both wet and dry microbursts over the continental United States. They are produced hourly during the convective season and can be viewed at *orbit-net.nesdis.noaa.gov/arad/fpdt/mb.html*

Low Cloud and Aircraft Icing Products

Detection of fog and low clouds, particularly at night, is important to aviation activities. A GOES product utilizing two infrared channels (10.7mm and 3.9mm) can help determine the areal extent of this cloudiness at night over the continental United States and Alaska every 30 minutes. An experimental fog depth image is produced hourly. An experimental cloud base height product for the West Coast was added in 2000 to estimate low ceilings (< 1,000 ft) that are critical to aviation operations. Fog products can be found at *orbit-net.nesdis.noaa.gov/arad/fpdt/fog.html*. By combining information from the visible and longwave infrared (12.0mm) channels to the two described above, areas of possible aircraft icing can be delineated. The icing product is available hourly and can be viewed at *orbit-net.nesdis.noaa.gov/arad/fpdt/icg.html*.

Geostationary Sea Surface Temperatures

GOES-8 and GOES-10 are proving capable of producing sea surface temperatures (SST) over most of the Western Hemisphere nearly continuously. The accuracy and spatial resolution achieved with the GOES measurements are close to that achieved from the polar orbiting platforms, and GOES has a unique advantage of high temporal sampling frequency. For the

SST determination, the frequent sampling by GOES makes a more complete map of SST possible after clouds have moved on. Cloud detection is enhanced by noting that a change in scene temperature over a short period of time may indicate the presence of clouds. The abundance of GOES observations helps to maintain a balance between high-quality, cloud-free observations and good geographical coverage of SST estimates. For the first time, GOES is enabling quantification of the diurnal variation of a radiometrically determined SST over large areas and long time periods. This quantification may have important implications in both numerical weather prediction and climate monitoring. NESDIS has been producing the GOES SST hourly since December 1998 for both GOES-8 and GOES-10 and had planned to declare the product operational by June 2000. A global SST product is produced every three hours; regional SST products are generated every hour. These products were planned for operational implementation in 2000.

Volcanic Ash Monitoring

Techniques that use the imager and sounder channels on GOES-East/West are being developed to assist in the tracking of volcanic ash cloud plumes (Figure 3-DOC-7). One product that employs three channels (10.7μm, 12.0μm, and 3.9μm) has been developed and is under evaluation. Ash cloud advisory statements are provided by NESDIS to the aviation community over southern North America and northern South America, through the Volcanic Ash Advisory Center in Washington, District of Columbia. The experimental volcanic ash product is produced hourly for several active volcanic areas and made available on the Web at *orbitnet.nesdis.noaa.gov/arad/fpdt/volc.html*.

Fire and Smoke Monitoring Algorithms are being developed to detect fires and to monitor their growth and the associated smoke coverage. The GOES-8 split window data (at 4μm and 11μm) have been used to assess trends in South American burning practices over the past 6 years (1995-2000); GOES detected the most fire pixels in the tropical rain forest ecosystem in 1995. The application to clear sky human-initiated burning in South and Central America is now being adapted to monitor cloudy sky lightning and clear sky human-initiated fires in the Canadian provinces and the continental United States. The continual monitoring from GOES (as often as every 7½ minutes) can assist firefighters to plan evacuation and extinguishing activities. NESDIS planned to test the routine production of a fire product in the summer of 2000. Studies with Brazil are underway to predict smoke transport and air pollution and health alerts for major cities. An AVHRR fire detection algorithm is being developed for use in monitoring fire and smoke outbreaks around the world. This algorithm is being implemented in a Hazard Mapping System that will provide analysts a means to look at fire and smoke events as well as other environmental hazards, and provide the data to users and the media.

A GOES Products and Services Catalog is available on line at *orbitnet.nesdis.noaa.gov/arad/fpdt/goescat/index.html*. An up-to-date list and description of operational and experimental products with links to the real-time products are available from this web page. A Polar Products and Services Catalog is under development and is planned for 2001.

NPOESS

ORA scientists continue to play an important role in the evaluation of proposed contractor sensor design and retrieval methods during the ongoing selection process for NPOESS. ORA scientists have created a variety of "test bed" data sets that are being used in the algorithm evaluation process. This is accomplished through participation in operational algorithm teams with the long-term goals of assuring capability to meet the requirements of all Environmental Data Records. Ozone evaluation, calibration, and validation activities will take place for the new

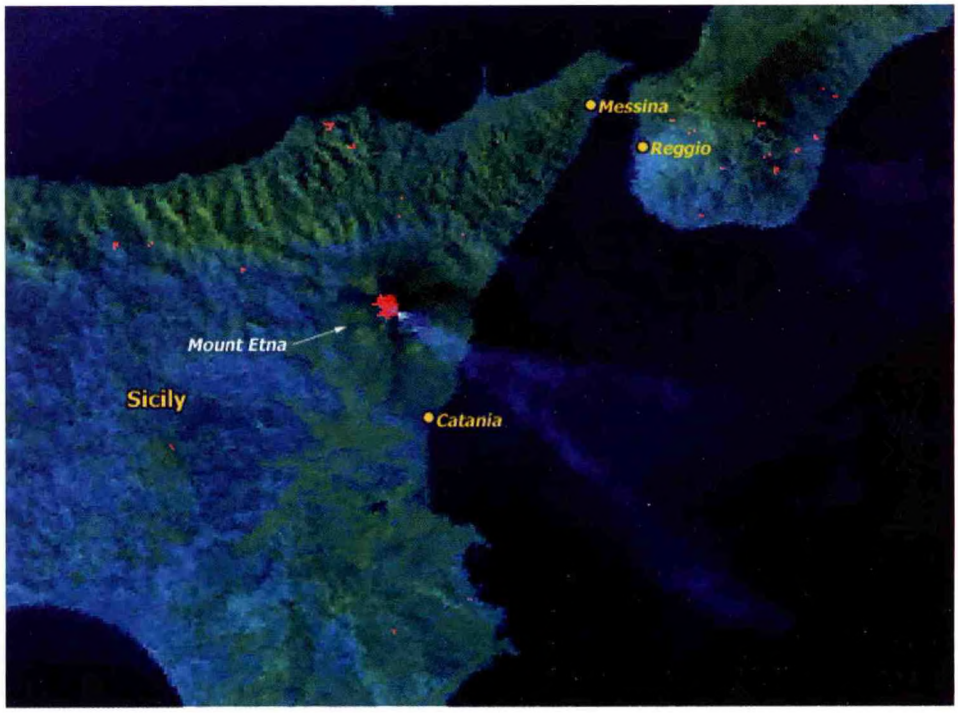


Figure 3-DOC-7. Strong heat signature (red) and an ash plume associated with eruptions of Mount Etna volcano in northeastern Sicily. Other visible hot spots in image are probably due to wildfires.

Solar Backscatter Ultraviolet Instrument (SBUV/2) instrument after the launch and successful checkout of NOAA-L. A new ozone profile retrieval algorithm (Version 7) is under development at NASA. As soon as it becomes available, NOAA will begin to incorporate it in its SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-11, -14, and -L, and with the TOVS instruments on NOAA-14, -15 and -L. Experimental high temporal ozone products are also being produced from the GOES-8 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

Land Surface Parameters for Use in Weather Forecast Models

Satellite-derived fields of land surface characteristics are being prepared for use in NWP models. These include radiation products delivered in near real-time as forcing variables, surface characteristics, such as fractional green vegetation and albedo, that specify model lower boundary conditions and validation quantities, such as surface temperature. These products are meant to help the NWP models maintain better soil moisture fields which in turn results in better near surface temperature and humidity forecasts, and better precipitation forecasts. These fields now include POES-based (SSM/I and AMSU) estimates of surface emissivity, snow cover, sea-ice extent and concentration, land surface skin temperature, and soil wetness. Development of snow depth is underway. Forward models for surface emissivity at various microwave frequencies have been developed and are being tested in the forecast models. Algorithms to determine clear sky ice surface temperatures have been developed and delivered to Atmospheric Environmental Services, Canada for evaluation.

Clouds from AVHRR

Algorithms are being developed, tested, and validated for determining cloud optical and microphysical properties from imager data such as the AVHRR. These algorithms are in addition to those already developed which estimate amounts and types for each observed cloud layer. The four cloud types are: L - Liquid Water Clouds; M - Mixed Phase Clouds; G - Glaciated Clouds (opaque); and H - High Ice Clouds (semi-transparent). Knowledge of cloud properties is important for both climate-scale and short-medium range forecasts. Accordingly, algorithms and processing systems to estimate cloud properties from imager data are being developed for both applications. Assimilation of cloud properties into NWP models is an objective of NCEP for improving short-medium range forecasts. Other applications of this work include the validation of simulated scenes to be used for evaluation of new algorithm and instrument designs which is supported by the IPO. In addition, new algorithms are being developed to produce optimal estimates of cloud properties from both imager and sounder data, such as the merge of AVHRR and TOVS data.

Aerosols

An algorithm for the correction of a thermal radiation leak in the 1.6μm reflectance channel of the Tropical Rainfall Measuring Mission (TRMM) satellite's Visible Infrared Scanner (VIRS) has been developed. It is being applied to VIRS raw data prior to application of the NESDIS operational aerosol retrieval algorithm by NASA's Clouds from the Earth's Radiant Energy System (CERES) instrument data processing team. Without this correction, the aerosol optical thickness at 1.6μm would be overestimated by as much as 200 percent, depending on the temperature of the Earth's surface. In FY 2001, we will validate retrievals of aerosol optical thickness (AOT) and the Angstrom Exponent, a measure of the size of particles in the atmospheric column derived from optical thickness measurements at 1.6μm, and 0.63μm, the other reflectance channel of VIRS. Validation will be accomplished by comparison with sun-photometer measurements of solar extinction at five wavelengths from 15 island and coastal locations established by NASA's Aerosol Robotic Network (AERONET). This algorithm will also be applied to NOAA-L AVHRR data (after its launch) which has the same two reflectance channels as VIRS plus an 0.83μm reflectance channel. This information on aerosols will be used to correct for the attenuation of aerosol particles in the infrared channels of the AVHRR instrument to remove errors in the retrieval of sea surface temperature. The correction algorithm will initially be derived from the multi-year archive from the AVHRR Pathfinder Atmosphere (PATMOS) data set using a single channel AOT retrieval at 0.63μm. The long-term record of AVHRR SSTs can be corrected for aerosol induced errors which currently limit the utility of these data for climate change studies. Finally, an algorithm for the estimation of aerosol optical thickness over dark vegetated land surfaces will be developed in support of NASA's Global Aerosol Climatology Project (GACP). It will also utilize the PATMOS archive of clear-sky reflectances at 0.63μm collocated with sun-photometer observations of AOT at non-coastal land based AERONET stations to make empirical adjustments to the surface reflectance model used in the NESDIS operational aerosol retrieval algorithm used over oceans. This will be the first globally applicable aerosol retrieval algorithm for land areas and will be used by NASA and NOAA to create a climatology of aerosol optical thickness over land for climate change studies.

Long-term Monitoring of NOAA-15 Advanced Microwave Sounding Unit-A (AMSU-A) Performance

Since the launch of the NOAA-15 satellite, the AMSU-A level 1B data have been captured from the CEMSCS and stored on optical disks. These data are used for off-line characterization of the instrument radiometric performance on orbit. Over 20 important radiometric parameters are extracted or calculated from the AMSU-A 1B data. NESDIS has already demonstrated that the noise in the observations in all channels is lower (better) than that required by the specifications and, in some channels, it is lower than estimates based on pre-launch test results. In FY 2001, NOAA will examine the other radiometric parameters. NOAA will also continue compiling long-term trends of all the parameters to provide a better understanding of the instrument performance. The PC-based software developed for evaluating these data will be improved for better efficiency in processing the data.

Calibration of the Visible and Near-Infrared Channels of the AVHRR

The AVHRR flown on POES is recognized as an invaluable resource for satellite-based studies of the Earth system. The long-term records of geophysical products such as the Normalized Difference Vegetation Index (NDVI), columnar aerosols over the oceans, cloud morphology, and short-wave radiation budget play a central role in climate and global change studies by providing a means to study the environment continuously. It is thus very important to characterize and document the in-orbit performance of the AVHRR flown on the polar orbiters. Toward this end, a very comprehensive program of post-launch calibration and characterization of the AVHRR has been implemented to ensure the accuracy, continuity, and viability of the various AVHRR-derived geophysical products, with particular attention paid to the visible (Channel 1: 0.58 - 0.68 μm), and near-infrared (Channel 2: 0.72 - 1.1 μm; Channel 3A: 1.58 - 1.64 μm) channels which do not have any onboard calibration devices. The major program elements are: (a) development of an optimal vicarious post-launch calibration technique, utilizing radiometrically stable calibration sites, model simulations of the radiation measured by the sensors, and simultaneous radiation measurements by the AVHRR and by calibrated spectrometers onboard aircraft; (b) enhancement of available vicarious calibration techniques to improve attainable radiometric calibration accuracies beyond ± 5 percent; (c) evaluation of the feasibility of using the International Space Station (ISS) as a platform to calibrate satellite sensors, in general, using radiometers on the ISS traceable to the National Institute of Standards and Technology (NIST); (d) establishment of the AVHRR as a traveling calibration standard to monitor the performance of sensors, such as the imager on the GOES, the visible channel of the High-resolution Infrared Radiation Sounder (HIRS), the Moderate-resolution Imaging Spectrometer (MODIS), and various sensors to be flown on ENVISAT; and (e) design of optimal onboard and vicarious calibration techniques for the visible and near-infrared sensors planned under the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The relevance and importance of these activities has been recognized by the national and international user community, as evidenced by the appreciation and endorsement of the Working Group on Calibration and Validation (WGCV), Committee on Earth Observation Satellites (CEOS), and the Global Observing Systems Space Panel (GOSSP). To ensure global access to the results of the above program, and recognizing the importance of the AVHRR-derived products to national and international programs, such as the International Satellite Cloud Climatology Project (ISCCP), the International Geosphere Biosphere Programme (IGBP), the Global Climate, Ocean, and Terrestrial Observing Systems, and to benefit from sensor calibration research elsewhere, active liaison, and collaboration in some instances, has been established with researchers in NASA, NIST, EUMETSAT, China Meteorological Administration, Beijing, China; Rutherford Appleton Laboratory, United Kingdom; National Space Development Agency, Japan; the NOAA/NASA Pathfinder Program; several space agencies and remote sensing laboratories outside the United States, and academia both in the United States and abroad. Accomplishments to date include near real-time updating of the calibration of the AVHRR on NOAA-14; determination of the in-orbit degradation of the AVHRR on NOAA-15 within six weeks after launch, and the evaluation of the performance of the visible channel of HIRS on NOAA-14, using the AVHRR as a calibration standard. Dissemination of the information resulting from the calibration activity is accomplished through presentations at the meetings of learned and professional societies, publications in the literature, and through the electronic media.

Calibration of Geostationary Operational Environmental Satellite Instruments

The wavelength configuration of channels on the Geostationary Operational Environmental Satellite-M (GOES-M) Imager will be slightly different from that of its predecessors. The current 12μm channel will be replaced by one at 13.3μm. The new channel will employ a single detector with an 8-km field-of-view at the Earth's surface. The water-vapor channel at 6.7μm, which on GOES I through L observes the Earth with a single 8-km detector, will employ two

4-km detectors on GOES-M. To accommodate these revisions, the calibration processing in the ground system will be modified.

Pathfinder

Climate data sets of cloud amount, aerosol optical thickness (AOT) over the oceans, and the Earth's radiation budget for clear and cloudy skies have been retrospectively generated from over 17 years of AVHRR data as part of the NOAA-NASA Pathfinder program. An improved data set spanning the period from July 1981 through the end of 1999 was completed in 2000. This data set is being utilized to study the relationship between the variation in global mean values of the absorbed solar radiation and variation in aerosol amount caused by major volcanic eruptions. The influence of the aerosol amount on variations in the global surface temperature is also under investigation. Analysis of time series of anomalies of the cloud radiative forcing have been shown to correlate well (spatially and temporarily) with El Niño events. A second reprocessing of the entire data set is being proposed, where multiple-layered cloud data will be used. Land surface and ocean products such as the vegetation index and the sea surface temperature will be added.

Ocean Surface Winds

Calibration and validation studies are performed for all new operational ocean surface wind data streams. Product refinement and development activities are currently underway to improve ocean wind vector retrievals in the high wind speed regime where current retrieval algorithms underestimate the wind speeds. There are several satellite-based active and passive microwave sensors planned for launch in the near future that NOAA will have the opportunity to obtain near real-time data streams from. One of these sensors will be the first demonstration of the passive polarimetric technique, which is the technique that is being depended on for NPOESS to meet the nation's ocean surface wind vector requirements.

Storm Signatures and Winds from Synthetic Aperture Radar

ORA scientists are currently studying ocean surface wind signatures of atmospheric fronts and storms with synthetic aperture radar (SAR) imagery. By sensing variations in ocean surface roughness on the centimeter scale, SAR sensors can image storms, atmospheric waves (such as coastal lee waves), atmospheric fronts, and coastal wind shadowing. Techniques for calculating wind speed (and under certain conditions direction as well) are also under development. A near real-time demonstration of SAR applications in Alaska was conducted in the fall of 1999 using data from the Canadian RADARSAT satellite. SAR images of the Bering Sea and northern Gulf of Alaska were provided to the NWS Anchorage WFO for analysis of wind conditions, location of polar lows, and position of the ice edge. Wind speed images derived from SAR were also provided along with other wind data from scatterometer winds to allow meteorologists at the Anchorage office to assess the utility of SAR data and derived products to their operational weather analysis and forecast activities. Before the year 2003, four new wide-swath SAR satellites are planned for launch. If data acquisition and sharing arrangements can be made to obtain access to SAR imagery from these new sources, frequent routine SAR coverage of United States coastal areas will be possible.

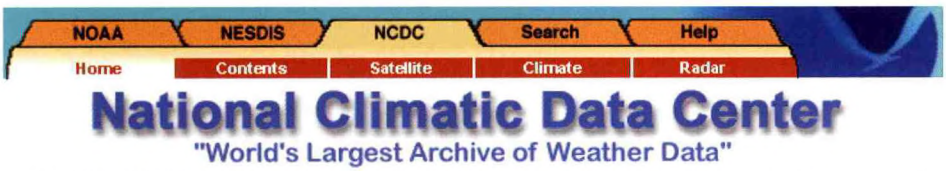
Ocean Color

Several programs at ORA are involved in satellite ocean color research. The Marine Optical Buoy (MOBY) Project develops, deploys,and maintains the MOBY off of the coast of Lanai, Hawaii, to measure visible and near-infrared radiation entering and emanating from the ocean. The resulting measurements support the initialization and vicarious calibration of international and national ocean color sensors, such as the Ocean Color and Temperature Sensor, the Sea-Viewing Wide-Field-of-View Sensor, and the recently launched Moderate Resolution Imaging Spectroradiometer. The Marine Optical Characterization Experiment (MOCE), MOBY's sister project, involves the collection of insitu measurements of these and other parameters relevant to ocean color in the surrounding region from ship. Data from both sampling platforms furnish a time-series of bio-optical measurements that is employed to track sensor drift, define bio-optical relationships, validate satellite-derived products, and develop ocean color algorithms. In addition to MOBY and MOCE, programs exist at ORA to routinely evaluate the accuracy of NESDIS operational ocean color products and to develop algorithms in order to remotely detect and predict the presence of noxious marine biota, such as harmful algal blooms.

Coral Reef Watch: NOAA's Early Warning System for Coral Reef Health

Like the rest of the world, most of the United States coral reef systems are threatened due to pollution, over-fishing, and thermal bleaching. This threat includes almost all of Florida and Puerto Rico reefs, nearly half of Hawaii's, and an unknown but significant fraction of United States Pacific Territories. The widely-distributed and isolated location of many coral reefs preclude normal monitoring practices. In 1998, NESDIS established an experimental capability using POES satellites to conduct thermal bleaching surveillance of coral reefs on a worldwide basis. This experiment demonstrated remarkably accurate capabilities for early warning of El Niño-induced coral reef bleaching conditions over all global tropical ocean regions resulting in a special International Workshop on Satellite

Monitoring of Coral Reefs being convened in June 1999. A Coral Reef Watch Program was proposed to (1) transition existing experimental satellite reef health monitoring capabilities into a viable operational capability, (2) formalize the existing United States leadership in the emerging global" Virtual Coral Reef Ecosystem Monitoring Laboratory," and (3) provide for a solid scientific basis for future monitoring and assessment products/capabilities.



ENVIRONMENTAL DATA CENTERS

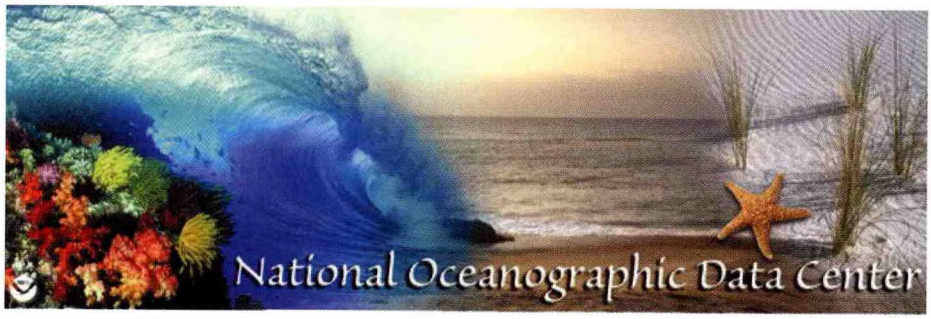
National Climatic Data Center (NCDC)

NCDC has the responsibility for long term stewardship and access to the Nation's climatological data. To meet this responsibility:

- NCDC performs data management and access functions regarding retrospective meteorological data, including data from *in situ* (ASOS, AWOS, Rawinsonde, COOP, etc.)and remote sensing sources (satellites, radars, etc.). Such functions include: acquisition (ingest, to include inventories), quality control processing, archiving, access, indexing, quality assessment, evaluation, synthesis, and dissemination of data collected by global and national meteorological observation networks or systems. Meteorological data that have enduring value to the Nation and are sufficient to describe the climate are included.
- NCDC serves as the Nation's official Data Center for Climatological Data, as such part of the Federal Records Retention System (FRRS). Follows NARA guidelines and policies for meteorological data records and information.
- NCDC partners nationally with National Aeronautical and Space Administration (NASA), Department of Defense (DOS), Environmental Protection Agency (EPA), Department of Agriculture (USDA), Department of Energy (DOE), Department of State (DOS), National Science Foundation (NSF), Geological Survey (USGS), Global Climate Research Panel (USGCRP), and others.
- NCDC partners internationally with: World Meteorological Organization, International Council for Science, World Data Centers, Bilateral Agreements, Intergovernmental Panel on Climate Change, UNESCO.
- NCDC maintains national and global baseline data sets for analyses of long-term climate trends and for monitoring global change i.e. Global Historical Climatology Network (GHCN), United States Historical Climatology Network (USHCN), Comprehensive Ocean-Atmosphere Data Set (COADS), and Comprehensive Aerological Reference Data Set (CARDS).
- NCDC serves as the World Data Center for Meteorology at Asheville, under the auspices of the International Council for Science. In this capacity, NCDC archives the data collected by internationally sponsored research programs and actively exchanges climate data with foreign countries.
- NCDC provides facilities, data processing support, data exchange, and expertise, as required, to meet United States commitments to foreign nations, international organizations, and to WMO programs.
- NCDC is one of the archive locations for the NCEP/NCAR Re-analysis data set. NCDC will supplement what other agencies (NCEP/CEP and ERL/CDC) have done in making portions of this data set available on-line. NCDC will place the Re-analysis model input data on-line.
- NCDC manages the Regional Climate Center (RCC) Program consisting of six facilities. These Centers, located at universities or state agencies, provide data collection, user services, and applied climate research on a regional basis. NCDC also coordinates the State Climatologist (SC) programs. Along with the NCDC, the RCCs and the State Climatologists form the national climate services program.

National Oceanographic Data Center

The National Oceanographic Data Center (NODC) supports climatic services and research through its data management and data services activities. NODC provides data management for major climate-related studies, such as the TOGA program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). NODC performs a number of functions for the Global Temperature Salinity Profile Program (GTSPP), including incorporation of real-time and delayed mode data into a continuously managed data base. GTSPP makes global temperature and salinity data quickly and easily accessible to users. NODC also provides data products and services individually to researchers as well as to members of the operational marine community, e.g., the Navy, Coast Guard, and shipping industry. NODC distributes on CD-ROM the Atlas of Surface Marine Data, which includes global surface marine observations, taken from COADS files. It also includes objectively gridded fields of surface marine fluxes of heat, momentum, and fresh-



water. NODC also archives and distributes on CD-ROM surface marine data collected by NOAA's Coastal - Marine Automated Network (C-MAN) stations, and NOAA moored buoys. Both products are described on NODC web pages, and made available through the NOAA National Data Centers' (NNDC) Online Store.

National Geophysical Data Center

The National Geophysical Data Center (NGDC) manages geophysical data and information resources for NOAA and the scientific community within the disciplines of solar-terrestrial physics, paleoclimatology, snow and ice, marine geology and geophysics, and solid earth geophysics. NGDC participates in national and international programs that collect and provide data for research in meteorology, climatology, and space weather. NGDC operates World Data Centers for Solar-Terrestrial Physics, Paleoclimatology, Marine Geology and Geophysics, Solid Earth Geophysics, and Snow and Ice under the auspices of the International Council for Science. NGDC operates the secretariat for the Scientific Committee for Solar-Terrestrial Physics.

NGDC provides data processing, access, management, archive, analysis, research and stewardship services for space weather, paleoclimatological, cryospheric, and some meteorological databases collected on satellites and by ground-based observatories. Space environment data collected on GOES and POES satellites and space environmental, meteorological and oceanographic data collected on DMSP satellites are officially archived by the Solar-Terrestrial Physics Division. Ground-based measurements of solar activity, ionospheric structure and geomagnetic variations used in space weather forecasts, warnings and alerts are archived at NGDC. The Paleoclimatology Group operates NOAA's Paleoclimatology Program, which manages geophysical data used to derive paleoclimate data and information. Cryospheric data from ground-based and satellite instruments are managed by the National Snow and Ice Center, which is affiliated with NGDC.

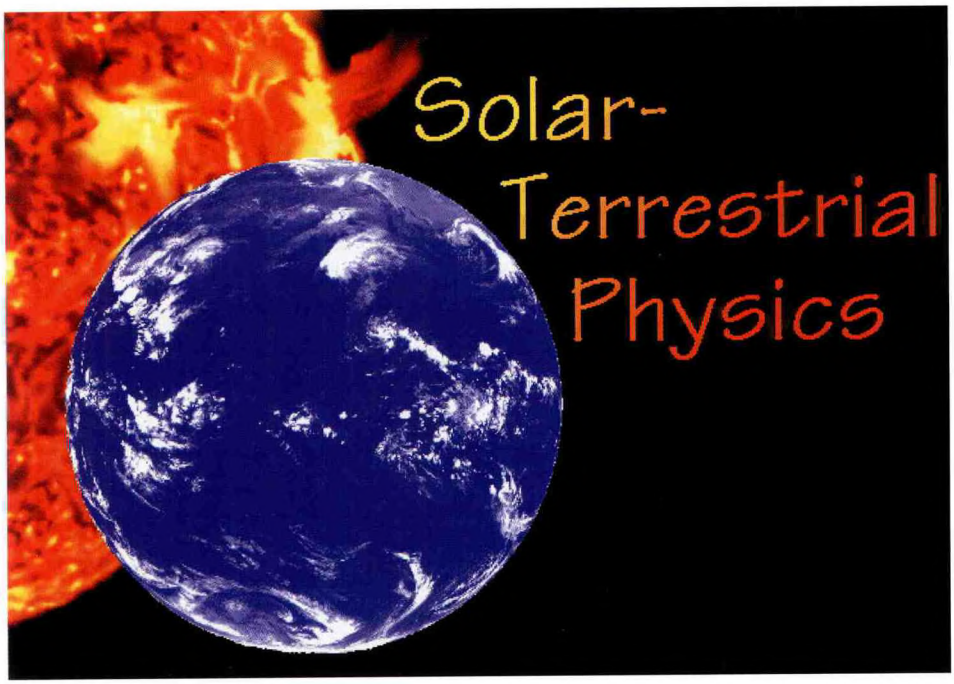
New technology presents new opportunities and challenges for NNDC and the World Data Center system. NGDC uses WWW-based applications to provide improved, more timely services including data discovery, automated inventories, on-line catalogs, interactive data display, data mining, and data delivery. As a result, the number of users has increased dramatically. Since most of the new users are less familiar with the data than the research community, additional burdens are placed on the NNDC's to assure that quality data are provided in a display that is easy to understand and in a format that is easy to use. At the same time, new applications are under development, which increase the need for quality data; they are the mining of information from the data archives and the running of data-driven numerical models from remote locations (*www.ngdc.noaa.gov*).

NOAA's Defense Meteorological Satellite Program (DMSP) at NGDC prepares research quality data recorded by scientific instruments on DMSP operational satellites for retrospective analysis and the official archive. Data sets include visible, infrared and microwave imagery, microwave soundings and *in situ* measurements of the space environment. The official archive is used to prepare products, derive geophysical parameters including atmospheric and ionospheric principal components, and provide user services. New user services are provided through the Space Physics Interactive Data Resource (*www.ngdc.noaa.gov/dmsp*).

NOAA's paleoclimate program to assemble global information on paleoclimate is operated by NGDC. The program has acquired many paleoclimate databases derived from geophysical data, namely tree-rings, pollen and macrofossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources. Paleoclimate databases can be displayed, searched, and retrieved using custom software (*www.ngdc.noaa.gov/paleo*).

The Space Weather program at NGDC prepares research quality data of the near-Earth space environment for retrospective analysis and the official archive. GOES, DMSP, and POES satellites carry instruments that monitor the space environment; for example, the SEM instruments on GOES and POES and the SSIES, SSJ/4 and SSM instruments on DMSP. Future instruments, namely the GOES Solar X-Ray Imager and two DMSP Ultraviolet Imagers, will greatly increase both the use and volume of space sensor data. Other data sets in the space weather archives include measurements of solar activity, solar flares, magnetic activity, magnetic storms, ionospheric parameters, and ionospheric storms collected by NOAA and other agencies. The STP program has a long and successful history of cooperating with NASA, USGS, DOD, academia and other NOAA components. The STP program at NGDC

archives measurements of total solar and solar spectral irradiance for use in climate studies. The data sets are recorded on NOAA and NASA satellites and irradiance values inferred from ground-based solar imagery (*www.ngdc.noaa.gov/stp/stp. html*)



The National Snow and Ice Center(NSIDC) at the University of Colorado is associated with NGDC and maintains several cryospheric-related data sets of interest to meteorology and climatology. These data sets include a collection of historical photographs of glaciers, temperature, pressure and position data from drifting buoys placed on the central Arctic pack ice, and data from the NOAA snow cover and DOD-NOAA sea ice chart digitizing projects. NSIDC provides data management services for a variety of cryospheric research programs sponsored by NASA and NSF. In addition, NSIDC has developed gridded sea ice products (sea ice concentrations and multi-year ice fraction) based on passive microwave data collected by NASA and DMSP satellites. NSIDC is acquiring snow cover, glacier and sea ice records from the former Soviet Union. Online services are available, at *www-nsidc.colorado.edu.*

SUPPORTING RESEARCH

CLIMATOLOGY

Global Historical Climatology Network (GHCN)

The GHCN data set is a comprehensive global surface baseline climate data set designed for monitoring and detecting climate change. Comprised of surface station observations of temperature, precipitation, and pressure, all GHCN data are monthly values. Users of the NCDC web site can now view the spatial distribution of global temperature and precipitation trends and anomalies through a new interactive web page. This page can be accessed through the GHCN web page (*www.ncdc.noaa.gov/cgi-bin/res40.pl?page=ghcn.html).*

Blended Temperature Project

A global surface temperature data set was produced from numerous sources including sea surface temperatures (SST), land surface temperatures, and satellite data using the special sensor MSU which collects data over land areas that are not snow covered. Additional coverage over snow covered areas will soon be provided via the MSU on board the TIROS weather satellite.

New Climate Atlas of the United States

The purpose of this new atlas project is to depict the climate of the United States in terms of the distribution and variation of major climatic elements. The Climate Atlas will meet the needs for climatic information from research, commercial, industrial, agricultural, educational institutions, as well as from the general public. Information contained in the atlas will be used for planning, engineering, and scheduling purposes. The new atlas when completed, should contain several hundred updated high resolution GIS generated maps.

Climate Reference Network Project

The United States Climate Reference Network (CRN) is a network of climate stations now being developed as part of a NOAA initiative. The primary goal is to provide future long-term homogeneous observations of temperature and precipitation that can be coupled to past long-term observations for the detection and attribution of present and future climate change. The CRN will also provide the United States with a reference network that meets the requirements of the Global Climate Observing System (GCOS). The stations will monitor temperature, precipitation, solar radiation, and wind speed. Hourly observations of these variables will be transmitted in real-time.

Climate Monitoring

The NCDC Climate Monitoring Group produces operational as well as special-event reports on climate and weather around the globe. These NCDC reports address the climate in historical perspective and are available via the NCDC web site. Highlights include: synopses of global monthly and annual mean temperatures and precipitation and their departures from the long term mean; global and United States extreme events; and United States and global regional analyses using traditional surface data as well as blended surface and satellite data products. The monitoring group also

responds to high level NOAA and executive level governmental requests concerning the state of the national and global climate. The products and reports address the climate in historical perspective and are available via the NCDC WWW site at *www.ncdc.noaa.gov*.

Paleoclimatology

NOAA's paleoclimate program to cooperate in research projects to use the combined global paleoclimate database for climate model verification and climate change studies is operated by NGDC. Objectives of the program are to cooperate with researchers and to conduct original research to describe the global patterns of annual-to-millennial scale climate change, to understand the causes of climate change, to separate man-induced climate change from natural variability, and to validate the models that are used to predict future climates. Support is received from the NOAA Climate and Global Change Program. More information is available at the NGDC website (*www.ngdc.noaa.gov/paleo/paleo.html*)

Environmental Remote Sensing

Operational meteorological satellite imagery provides a unique opportunity to monitor wildfires and population dynamics on global and nightly bases. NOAA's DMSP program at NGDC uses the nighttime imagery to locate sources of visible and infrared emissions including city lights, lightning, fires, flaring gas, and boats. Research projects use the city lights to infer population density, economic vitality, and carbon dioxide emissions. More information is available at the NGDC website (*www.ngdc.noaa.gov/stp/stp.html*).

Wildfires Monitored from Space

Operational meteorological satellite systems offer a unique opportunity to monitor wildfires because each satellite records infrared emissions covering the entire globe each day. An instrument designed to detect clouds also "see" fires, many of which burn in very remote areas. NGDC has developed a unique technique to capture nighttime emissions from both large and small wildfires. The system has been used to assist firefighters in developing countries. More information is available at the NGDC website (*www.ngdc.noaa.gov/dmsp/fires/globalfires.html*).

Space Weather

The Space Weather program at NGDC conducts original research in space physics with an emphasis on space weather applications. Research focused on numerical modeling of the ionosphere and magnetosphere is conducted with resident and visiting scientists from the United States and other countries. Research projects use the extensive integrated data bases archived at NGDC. In addition to building better models and improving our understanding of ionospheric and magnetospheric plasma processes, the research leads to improved data sets and new data products. NGDC has embarked on an environmental scenario generator project to mine information from the archives and to use the mined information to launch a numerical simulation of the atmospheric and space environment. More information is available at the NGDC web site (*www.ngdc.noaa.gov/stp/stp.html*).

OBSERVING SYSTEM PERFORMANCE INDICATORS

This multi-year effort will provide real-time information on the health and status of NOAA's observing networks. The developed system will continually monitor and assess the state of these networks with the intent of providing feedback that could either lead to improvements in the network or changes in analysis techniques to account for problems in the network.

OCEANIC AND ATMOSPHERIC RESEARCH LABORATORIES

Programs within the Oceanic and Atmospheric Research (OAR) Laboratories support various NOAA meteorological, oceanographic, and space science missions. The activities of OAR laboratories are oriented toward providing the scientific and engineering understanding, tools, and techniques that form the basis of improved national weather and climate services.

Special emphasis is placed on improving severe weather and hurricane warnings and forecasts and on improving the utilization and dissemination of data and information. Severe weather events include flash floods, strong winds, thunderstorms (including tornadoes, lightning, and hail), heavy snowstorms, extreme cold and heat, drought, and geomagnetic storms. The key contributions to improved hurricane forecasts fall under the "Hurricanes at Landfall (HaL)" focus of the United States Weather Research Program (USWRP). They include more accurate prediction of track, intensity, surface winds, rainfall, and human impacts. In pursuit of improved utilization and dissemination of data, the OAR laboratories conduct both in-house and cooperative research with other NOAA organizations, government agencies, joint institutes, universities, and the private sector.

Observing Technology

Two OAR laboratories in Boulder, Colorado, and one in Norman, Oklahoma, are heavily involved with developing new environmental observing system technologies. The Environmental Technology Laboratory (ETL) in Boulder, Colorado, develops and evaluates new remote-sensing concepts and systems. This development and the associated environmental research directly supports the Nation's forecasting and warning services. A comprehensive view of the laboratory and its research can be found on the Web (*www.etl.noaa.gov*). The Forecast Systems Laboratory (FSL) (*www.fsl.noaa.gov*) takes promising new scientific and engineering technologies from the research arena, helps develop them into mature engineering systems, and transfers these technologies to NOAA operations and the private sector. The National Severe Storms Laboratory (NSSL) (*www.nssl.noaa.gov*) located in Norman, Oklahoma, both develops new remote sensing systems and assists in the transfer of these technologies to the NWS.

A major example of these activities is the development of the world's first major wind profiler network. An outgrowth of early basic research at NOAA's Aeronomy Laboratory and extensive development at ETL, FSL now operates a network of 30 unattended wind profiling Doppler radars that provide profiles of high resolution winds aloft to National Weather Service (NWS) forecasters and modelers, universities, government researchers, and the private sector. Radio-acoustic sounding systems (RASS) comprising integrated wind profiler radars and acoustic sources are now capable of measuring temperatures as well as winds. The NOAA Profiler Network (NPN) has made significant contributions to improved forecasts and warnings since its completion in 1992.

In a continued collaboration between NWS and FSL, three NOAA profilers were recently installed in Alaska to support NWS volcanic plume tracking and hazard mitigation. All three profilers transmit at the new operational frequency of 449-MHZ. The engineering requirements for the transition of wind profilers from an experimental frequency allocation of 404.37-MHz came from collaborative efforts between FSL, ETL, and the United States Air Force.

In another example of technology transfer, FSL is collaborating with several universities, NOAA's National Geodetic Service, the United States Coast Guard, and the Federal Highway Administration to develop and deploy a network of surface-based water vapor observing systems for NOAA that utilize the Department of Defense's Global Positioning System (GPS). Some of these systems are installed at NPN sites. ETL and FSL will continue investigating the use of GPS receivers (surface and space-based) to achieve real-time, continuous observations of atmospheric water vapor for weather forecasting, climate monitoring, and satellite data calibration and validation. NRT GPS-IPG data with approximately 30-minute latency is now being provided for testing and evaluation.

FSL is investigating the use of superpressure balloons in the stratosphere as a platform for monitoring and observing the environment. Among the balloons' capabilities would be atmospheric soundings. The trajectory of the balloons could be controlled to some extent by adjusting their altitude so as to take advantage of the vertical shear. The balloons would carry compact, light-weight sondes whose locations could be tracked as they fell toward the surface. The balloons would comprise a moderately priced global system.

A number of engineering tests have already been performed at altitude by piggybacking on a zero-pressure balloon launched by the Physical Science Laboratory at New Mexico State University. Telemetry was received line-of-sight from a distance of over 200 miles, the storage batteries were charged by solar panels, the proper thermal environment was maintained during the daytime heating cycle, and the instrument package was successfully recovered after descent by parachute. In FY 2001, a 60-foot diameter superpressure balloon will be tested with an instrument payload.

During FY 2001, ETL and FSL will continue development of new sensors and innovative techniques for combining observing systems synergistically and economically. One effort involves the extension of wind profiler (RASS) and other data sources to develop humidity profiles through the planetary boundary layer. Other efforts include developing tools and techniques to integrate the data from surface-based and satellite-borne profiling systems for more effective use of these data in forecasts. In support of this effort, ETL has recently added a satellite remote sensing group that uses data from various environmental satellites to study air-sea interaction processes, the global hydrological cycle including water vapor and precipitation, and the Earth's radiation budget.

In a new development, ETL has demonstrated that tornadoes can be detected well before touch down by listening for their unique infrasonic signatures. Infrasonic antennas located in the central United States have been used to detect and locate numerous tornadoes. Verification has been provided by Doppler radar and visual sightings. This research effort is continuing and it is proposed that a network of these inexpensive infrasonic systems be deployed at WSR-88D sites to enhance early detection capability.

ETL will also continue development of Lidars and infrared Doppler multi-frequency radars as research tools to improve our knowledge of atmospheric winds, turbulence, and moisture processes. Development of dual-polarization Doppler and multi-frequency radars and passive radiometers will also be undertaken to study convective storms and their precursors, including in-cloud and entrainment processes. ETL will also continue research in the area of ocean remote sensing, including theoretical and experimental studies of rough surface scattering processes. In particular, ETL has demonstrated the potential application of Cold War-era over-the-horizon (OTH) surveillance radars for the large-scale mapping of ocean surface currents and winds. ETL is also developing an airborne Polarimetric Scanning Radiometer (PSR) designed to provide higher resolution measurements of sea state quantities, including surface winds.

The discussion of observing technologies would be incomplete without mention of the North American Atmospheric Observing System (NAOS) Program. The overriding purpose of NAOS is to make recommendations on the configuration of the upper air observing system over North America and adjacent water areas. Government organizations and universities in Canada, Mexico, and the United States support NAOS. About 15 agencies from these countries have representatives on the NAOS Council, which identifies issues, sets priorities, coordinates the work of the program, and seeks financial support. Eventually, the council will advise governments on how to: (1) improve the utility of existing observing systems and reduce costs, (2) design a cost-effective observing system for the 21st Century, and (3) evolve toward that system from the present one. OAR representatives serve on the NAOS council and its two principal working groups.

The NSSL, known for its role in the development of the WSR-88D NEXRAD radar, continues to improve the software algorithms used by the NWS forecasters. NSSL is also exploring ways to enhance the WSR-88D hardware using dual polarization techniques. The first step in this process is to prototype a new Radar Data Acquisition (RDA) for the WSR-88D capable of processing the additional information to produce the dual-polarization information. The next step will be to implement dual-polarization on the NSSL's WSR-88D research radar.

Tropical Atmospheric Research

The Tropical Dynamics and Climate Program of the Aeronomy Laboratory (AL) is using a network of remote-sensing wind profilers in a long-term study of tropical circulation and its impact on global climate. The Trans-Pacific Profiler Network consists of an array of wind profilers that make continuous measurements of atmospheric winds and other parameters in the tropical Pacific. In addition to 50-MHz wind profilers, the network is incorporating 915-MHz lower tropospheric wind profilers developed at AL. The observations, which extend from the boundary layer to the lower stratosphere, reveal the relationship between atmospheric vertical motions and convective systems in the tropics. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. The network will: (1) provide valuable improvements to the boundary layer and convective parameterization schemes used in general circulation models and (2) contribute to climate forecasting by furthering the understanding of the coupled ocean-atmosphere dynamics that governs the El Niño-Southern Oscillation (ENSO) phenomenon, the dominant component of interannual climate change. A description of the TPPN and access to the data can be found on the AL web page *www.al.noaa.gov/WWWHD/pubdocs/ElNino.html*.

Routine wind observations are made at Christmas Island using 50-MHz and 915-MHz profilers. Lower tropospheric wind measurements using 915-MHz profilers are made at San Cristobal, Ecuador; and Tarawa, Kiribati. In addition, surface and upper air measurements are being made at Nauru and Manus Island, Papua, New Guinea at sites collocated with the Atmospheric Radiation CART Sites (ARCS) maintained by the

Department of Energy (DOE), Atmospheric Radiation Measurement (ARM) program. The wind data are assimilated into the analyses and forecast models of the European Centre for Medium-Range Weather Forecasting (ECMWF), NCEP, and other meteorological centers. The data are also used by climate researchers to support investigations of the variability of tropical circulation systems.

A recent focus of research with profilers has been to support Ground Validation Field Campaigns for the NASA Tropical Rainfall Measuring Mission (TRMM). Profilers were operated in a vertical-only mode to observe the vertical structure and temporal evolution of precipitating cloud systems in the Texas Florida Underflights campaigns (TEFLUN) in April-May 1998 and August-September 1998, the TRMM LBA campaign in Brazil in January-February 1999, and in KWAJEX campaign in August-September 1999. In addition, a profiler was operated on the *R/V Ronald H. Brown* (Figure 3-DOC-8) during Nauru99 and KWAJEX to observe the vertical structure of precipitating cloud systems. The profiler observations are being made available to the TRMM Science Team. They will be the subject of collaborative research with other TRMM researchers in the coming years with an emphasis on the use of profilers to calibrate scanning radars used for TRMM ground validation research and the use of profilers to retrieve drop-size distributions and related precipitation parameters of interest to the TRMM Science Team.

Severe Weather Analysis and Forecasting Research

The NSSL in Norman, Oklahoma, focuses on research to understand and forecast severe weather systems and their associated hazards, such as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning-location networks. In addition, work includes assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, including research and development, for the WSR-88D program. In FY 2001, NSSL will continue to develop techniques in cooperation with the NWS to forecast and warn of weather hazards

Figure 3-DOC-8. NOAA Research Vessel Ron Brown.

to aviation and the general public. Work with the resultant data from the 1994-1995 VORTEX experiment and subsequent experiments like MEaPRS is continuing to provide new understanding of severe thunderstorms and the tornadoes that they spawn, to improve ways to model and predict these storms, and to provide new generation algorithms for severe storm detection. Immediate technology transfer will be effected by close association with the WFOs, such as those in Norman and Tulsa, Oklahoma; Phoenix and Yuma, Arizona; Melbourne, Florida; Pittsburgh, Pennsylvania; St. Louis, Missouri; Missoula, Montana; Reno and Las Vegas, Nevada; Jackson, Mississippi; Atlanta, Georgia; Fort Worth, Texas; Denver, Colorado; and Salt Lake City, Utah.

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

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

FSL will continue efforts toward effective assimilation of diverse observational data into numerical prediction models. Data from the Aeronautical Radio Incorporated (ARINC) Aircraft Communications, Addressing, and Reporting System (ACARS), WSR-88D Doppler radars, the NOAA Profiler Network, and weather satellites, especially GOES, are frequent and provide unprecedented resolution, either in the vertical or the horizontal, or both. These data are being more

fully exploited in the Local Analysis and Prediction System which provides highly detailed analyses and forecasts over areas hundreds of kilometers on a side, and the Mesoscale Analysis and Prediction System, the basis for operational and frequent short-term forecasts for the lower 48 states. The system has been incorporated into the AWIPS system and is being used by a number of other agencies, not only for various regions of the United States, but for a number of regions throughout the world.

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

A multi-year program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ETL and NSSL, the NWS Seattle WFO, NCAR, and the University of Washington. Support for the program is also being provided by the Office of Naval Research. This research improves understanding of the effects of prominent terrain on West Coast weather, with the ultimate goal of providing improved forecasts of coastal winds, precipitation, sea state, and storm surges. The emphasis is on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach involves special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft in FY 1994 and 1996, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of strong fronts and, in one case, an intense, landfalling low. The case studies from this work provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation. Follow-up field programs in FY 2001 and FY 2002 will focus on cloud and precipitation processes using special observations from research aircraft and land-based radars. The results are providing information on how to improve forecasts of Northwest weather.

Taking advantage of the 1997-98 El Niño event, ETL led the California Land-Falling Jets Experiment (CALJET) with participation by PMEL (OMIC), FSL, the Naval Research Laboratory (NRL), and the Naval Post Graduate School. CALJET took place between December 1997 and February 1998 and was designed to study the development of the pre-frontal low-level jet along the coast of California. This moist jet can cause severe, flooding rains along and near the coast as it impinges on the coastal mountains. The large volume of data gathered during this experiment, including those data from the NOAA WP-3 and from an array of radar wind profilers along the coast, was analyzed throughout FY 1998-99 to determine the mechanisms of jet development. This knowledge was incorporated into numerical models to improve the accuracy and lead time of forecasts of heavy, flooding coastal rains in California. This study is occurring with close cooperation between the scientists and the NWS forecasters in California (Figure 3-DOC-9).

Figure 3-DOC-9. CALJET sensor package

Mesometeorology and Precipitation Forecasting and Warning Research

NSSL develops techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Studies underway include the precipitation structure of mesoscale convective systems, the interactions between mesoconvective systems and the larger environment, the use of satellites to infer storm development and rainfall, short-range ensemble forecasting techniques, and winter storm forecasting procedures. In FY 2001, NSSL will continue to use polarization information to improve radar estimates of rainfall that will be the key to improving short-term flash flood forecasts. NSSL also continues to investigate various model convective parameterization schemes, along with our continued effort to improve model initialization through four-dimensional data assimilation.

In addition, NSSL is working with the NWS Storm Prediction Center (SPC) to improve their ability to forecast severe weather including winter weather events. Several new severe

storm and tornado climatologies have been completed. New experimental forecasts are now being produced by the SPC that include the probabilities of occurrence of severe weather. NSSL and SPC continue to improve the capability to forecast winter weather events and refine their ability to provide severe winter weather guidance products. In FY 2001, NSSL will continue to support the SPC by providing improved methods for severe weather forecasts including winter weather and flash floods.

Hurricane Analysis and Prediction Research

The Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory (AOML) explores hurricanes in dedicated research flights aboard the WP-3D aircraft operated by NOAA's Aircraft Operations Center (AOC). The P-3s carry a suite of instruments to measure a wide range of meteorological quantities, including standard flight-level data, precipitation characteristics, remotely-sensed surface winds, vertical soundings, ocean thermal structure, radar reflectivity, and Doppler radar winds. In addition to the airborne observations, HRD develops techniques for real-time analysis and display of hurricane data, especially of surface winds. It also carries out modeling and theoretical studies closely tied to the observational program and studies interannual and inter-decadal changes in hurricane activity.

The 1995-1999 hurricane seasons were the five most active consecutive ones in the >100-year quantitative climatology. There is a growing body of evidence indicating that the relatively low level of hurricane activity experienced in the 1970s and the 1980s is over and that the first decade or two of the 21st Century will see a return to the more active conditions that characterized the 1940-1960s. If this hypothesis proves true, land-use and development decisions made over the last two decades may be inappropriate to the present hurricane climatology and the need for more accurate forecasts and better informed policy guidance will become pressing.

An exciting new tool for this effort is AOC's newly commissioned Gulfstream IV (G-IV) jet which has operated successfully in the hurricane environment since 1997. The G-IV extends the envelope of observations throughout the depth of the troposphere. Use of these aircraft presents an unprecedented opportunity for better understanding and forecasting of hurricanes through detailed observations. Of special interest are the hurricanes' inner core, the oceanographic and upper tropospheric synoptic-scale forcings that control intensity and motion, and the kinematics and thermodynamics of the near-surface boundary layer. The GPS-based dropsondes procured as the G-IV's main scientific payload have a vital role in these investigations because of their high vertical resolution and superior thermodynamic and wind sensing capability. The 1998 season constituted the first major field program for HaL carried out in collaboration with NASA's Third Convection and Moisture Experiment (CAMEX-3). The success of this campaign combined with follow-on missions in 1999 was unprecedented. NOAA and NASA aircraft flew a combined total of more than 100 scientific sorties in 1998 and 1999. Participation by the G-IV and NASA's DC-8 and ER-2 provided extensive *in situ* observations above the middle troposphere for the first time since the 1960s. In addition to airborne measurements, university teams with instrumented towers, mobile Doppler radars, and portable profilers coordinated with HRD to obtain detailed measurements of near-surface conditions in most hurricanes that passed onshore during these seasons. Current plans are to repeat the 1998 campaign in conjunction with CAMEX-4 in 2001.

The motivation for acquisition of the G-IV was a statistically rigorous demonstration, based upon more than a decade of experiments with the P-3s, that intensive observations of the flows surrounding hurricanes can produce substantial (16-30 percent) reductions in track forecast errors. Data from multiple-aircraft experiments involving the G-IV and both WP-3Ds should confirm the GI-V's ability to improve forecasts. Adaptive targeting of aircraft observations to regions where they will do the most good is a strategy to realize even further improvement.

The forecast system currently has limited skill in prediction of intensity. Though continuing research with the expanded aircraft fleet, the Nation can realize large (billions of dollars per year) economic benefits through more accurate routine operational track forecasts. A second, equally significant, outcome is the promise of dynamically-based, skillful intensity forecasts. Because hurricanes inflict huge costs on the United States economy, even incremental improvements in forecasts have large benefit to expenditure ratios. The report on HaL by the USWRP Prospectus Development Team 5 (PDT5) contains a comprehensive, focused scientific strategy to realize these benefits (BAMS, 79, 305-323).

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

In the early 1990's, this research model proved so successful for simulation of observed storm behavior that the NWS adopted a version of it for

use in operational forecasting. From the 1995 through the 1999 hurricane seasons, the GFDL Hurricane Prediction System provided the most accurate hurricane-track forecast guidance available and contributed substantially to the dramatic error reductions in official forecasts that have occurred since its introduction.

Numerical Analysis and Prediction Modeling

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

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

Mesoscale Dynamics at GFDL develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies.

The FSL implemented a Rapid Update Cycle (RUC) at NCEP in 1994. The RUC gave a new analysis of surface and atmospheric conditions every three hours as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC was implemented at NCEP in February 1998. This new version operates at 40-km horizontal resolution with 40 vertical levels and provides updates every hour, thus, incorporating information from virtually all high frequency data sources: hourly wind profiles, WSR-88D (Doppler radar) velocity azimuth displays, ACARS reports (up to 65,000 per day), cloud-drift winds and estimates of total precipitable water vapor from the GOES satellites, and surface observations.

The new RUC also includes explicit forecasts of cloud droplets, ice crystals, raindrops, snowflakes, and graupel (snow pellets). This improves forecasts of precipitation type. The RUC exploits a new, multi-level soil and vegetation model to improve forecasts at and near the earth's surface. With the arrival of a larger computer at NCEP, the way is open for expanding the geographical domain of the RUC and moving toward finer resolution of the computational grid (20-km). The 20-km version of the RUC is expected to become operational in FY 2001. The new version will also incorporate a three dimensional variational (3DVAR) analysis that will replace the optimum interpolation method used earlier.

Along with NCAR, NCEP, and a few universities, FSL is collaborating on the development of a new mesoscale model, the Weather Research and Forecast (WRF) model. The goal of this development, from the beginning, is that the WRF model should become a community model and a tool both for experimental and operational prediction, thus paving the way for quick realization of research advances in forecast dissemination to the public and industry. A management plan has been published, and working groups are organized to pursue various aspects of development.

The Air Resources Laboratory is also involved in the development of new models for operational use by NCEP. The main focus is on mesoscale models and in the development of new capabilities for data assimilation. In particular, the new generation of mesoscale models (such as the WRF model referred to above) will require advanced descriptions of the coupling between the air and the surface, a matter that is being studied intensively in ARL programs involving closely interacting measurement and modeling activities. ARL conducts research on the surface energy balance and on the spatial variability of surface fluxes using aircraft. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as of emissions from sources like volcanos and industrial enterprises. In recent work, ARL is developing a new system for forecasting the dispersion of smoke from forest fires, in collaboration with the Association of South East Asian Nations and their Regional Haze Action Plan.

Air Quality Research

The principal mission of the Air Resources Laboratory (ARL) is to improve the capability to forecast changes in air quality and atmospheric deposition. Deposition is the factor that links the pollutant characteristics of the air with the terrestrial and aquatic environments. ARL's research focuses on the lower atmosphere, where the atmosphere is in direct contact with other media--aquatic, terres-

trial, and biospheric. The core of ARL research relates to studies of the atmosphere as a component of the total environment. Much of this work is in collaboration with other parts of NOAA (principally NCEP) and with other agencies, such as EPA, DOE, and DOD.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs, and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Carolina, develops predictive models on local, regional, and global scales for assessing changes in air quality and air pollution exposure as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards. The Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models. The Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales, and specializes in the development of high-technology airborne instrumentation (for both aircraft and balloons). The Special Operations and Research Division, in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency prepared-ness and emergency response activities. SORD also serves as the main NOAA facility working with the Cooperative Institute for Atmospheric Studies and Terrestrial Applications (CIASTA) of the University of Nevada system.

ARL operates two national networks that focus research on the needs of the next generation of predictive models. The Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested-network with sites of varying complexity addressing evolving scientific issues of wet and dry deposition from the atmosphere. A major current item for scientific attention is the atmospheric deposition of nitrogen compounds and its role in promoting eutrophication of ecosystems, primarily coastal. The ARL-run Integrated Surface Irradiance Study (ISIS) serves as the national array of monitoring stations for solar radiation (and ultraviolet-B) with a subset of more advanced stations (the SURFRAD array) where both incoming and outgoing radiation components are monitored. Many of the SURFRAD stations are augmented with instrumentation to measure fluxes of sensible heat, latent heat, momentum, and carbon dioxide. Thus, the SURFRAD program is evolving into one of complete energy balance with supporting data on carbon dioxide exchange. This work forms an intersection with the new flux measurement networks in the United States and overseas, referred to as "Ameriflux" and "Fluxnet." All of this work is coupled with ARL research on atmospheric aerosols and with the development of new automatic methods for measuring cloud cover.

Much of ARL's research focus is on expressing air surface exchange processes in numerical models. To this end, ARL scientists have been instrumental in developing methods for describing areal air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. To test the aerial integration capabilities, ARL has instrumented an aircraft of the NOAA fleet (a DeHavilland Twin Otter) to measure all of the eddy fluxes as well as a number of trace gas exchange rates. This instrumented aircraft has been used in several field experiments and has already demonstrated that considerable error can result when local values are inappropriately taken to represent larger areas.

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

The Aeronomy Laboratory (AL) coordinates a NOAA/OAR air quality research effort, the Health of the Atmosphere research. NOAA's Health of the Atmosphere research is focused on the atmospheric science that underlies regional and continental air quality, with the goal of improving our ability to predict and monitor future changes, leading to improved scientific input to decision-making. NOAA/OAR's Aeronomy Laboratory, Air Resources Laboratory, Climate Monitoring and Diagnostics Laboratory, Forecast Systems Laboratory, and Environmental Technology Laboratory participate in the research. The Health of the Atmosphere research goals are:

- Characterize regional ozone episodes: Characterize the origin of ozone in rural areas, where crop and forest damage are of increasing concern. In 1999, a comprehensive air quality field experiment took place in the region around Nashville, Tennessee. In the summer of 2000, Houston will be the site of an experiment to investigate the complex chemical and meteorological factors that influence the air quality of that coastal region. The regional chemistry is of special interest because of the presence of large natural as well as anthro-

pogenic sources of hydrocarbons (including the petrochemical industry) and because of the unique influence of coastal meteorology on air quality of the region.

- Document trends in air quality: Help evaluate predicted atmospheric responses to changes in emissions (i.e., the ongoing measurements provided by the Atmospheric Integrated Research Monitoring Network (AIRMoN) and the ozone profiling network).
- Develop a better understanding of the fundamental science underlying the processes responsible for the formation and distribution of fine particles in the atmosphere: Improve the atmospheric predictive capability that links sources of fine particles and their precursors to human exposure and visibility impairment. In 1999, an experiment was conducted in Atlanta to compare research capabilities related to the measurement of fine particles in the lower atmosphere.

In future Health of the Atmosphere research, the OAR Laboratories will integrate their meteorological, chemical, and forecasting expertise to build an assessment and prediction capability for regional air quality that incorporates the influence of multiple-time-scale meteorology/climatology. While the ambient levels of pollutants like ozone and fine particles are clearly dependent on pollutant emissions, a large fraction of the variation in those levels is driven by meteorology, both in the short term and longer term. Therefore, the key to assessing both the intended long-term improvements in air quality and the more-episodic variations lies in understanding not only the atmospheric linkages between emissions and concentrations, but also in understanding the coupled chemical and meteorological processes. This "chemical meteorology" research will extend the current program focus on emissions/concentration linkages to include a predictive understanding of the role of synoptic, seasonal/interannual, and longer-term meteorological/climatological changes on the chemistry of the lower atmosphere. The Air Quality Research Subcommittee of the Committee on Environment and Natural Resources (CENR) will provide the interagency collaboration at the United States Federal level. On the broader international arena, the coordinating body is the North American Research Strategy for Tropospheric Ozone (NARSTO), a tri-lateral public/private partnership focused on ozone and particulate matter research in the United States, Canada, and Mexico. NOAA is the public-sector co-chair of NARSTO.

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

Space Environment Services

NOAA and the Air Force jointly operate the National Space Weather Operations group in NOAA's Space Environment Center (SEC) in Boulder, Colorado. In FY 2001, SEC will stress six strategic elements that include:

- Improvement of space weather products.
- Obtaining critical new space environment observations.
- Transitioning space weather analysis techniques and models into operations.
- Continued implementation of a modern computer architecture.
- Development of new web pages for providing space weather products.
- Fostering of a commercial vendor community for space weather services.

The improvement of services is built around the theme of making space weather information human friendly. Toward the same objective, a new NOAA Space Weather Scale has been designed and announced to the community. Space Weather products have been reorganized to include advisories in plain English and then replacement of little known vocabulary with descriptors that are understandable beyond the immediate field of space weather. The work toward new observations includes:

- Final planning for ingesting observations from the Solar X-ray Imager telescope to be flown on GOES M and following GOES spacecraft.
- Real time images of global aurora from the IMAGE satellite (Figure 3-DOC-10).
- A prototype test flight of a Hard X-Ray Spectrometer Telescope designed to detect precursors of solar radiation storms. The flight is being flown as part of the Defense Satellite Program.

The new NOAA Weather Scale identifies three types of space weather disturbances and describes five levels of

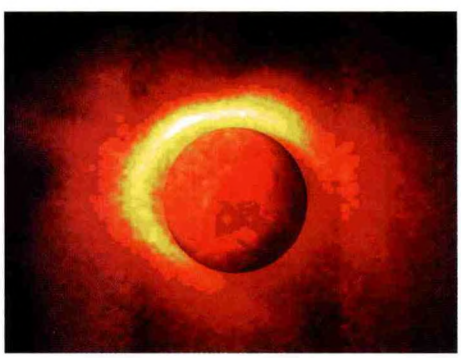


Figure 3-DOC-10. Ultraviolet image of sunlight scattered from the Earth's extended atmosphere of helium using the Extreme Ultraviolet Imager instrument. This image shows that the ionized helium atmosphere extends to about 2 - 3 times the size of the Earth. Irregularities at the fringe of the image, such as the upper left, indicate magnetic storm activity.

disturbance ranging from a Level 1--very mild to Level 5--extremely severe. The new web page design updates the SEC web page, an early leader in using the web to disseminate space weather alerts, warnings, and forecasts. With web page accesses exceeding one million per week and the increasing number of products and data, the old design had become unwieldy. The new pages will facilitate both experienced users and searchers new to the field of space weather.

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

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

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

SEC serves as the international World Warning Agency for the solar-terrestrial environment. It collects international data--solar-wind, X-ray, sunspot, corona, magnetic, etc.--in real-time and, from these data, provides International URSIgram and World Days Service and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use. There is also a substantial and rapidly growing customer base in the private sector. SEC operates with observations received from agencies that contribute their data and, in return, receive the synthesized and integrated services to meet their needs. Agencies making major contributions of data include: DOD, NASA, DOC, NSF, DOE, and DOI. SEC cooperates directly with NESDIS to receive solar X-ray, particle, *in situ* magnetic field, and plasma data from the SEM on GOES and the polar-orbiting NOAA satellites. Data are collected, stored, and displayed for analysis and products and distributed to outside customers primarily via the Internet (*www.sec.noaa.gov*), by NOAA Weather Wire, and digital data links (primarily operated by other agencies). Radio broadcast, mail, and recorded telephone messages are available to users as well.

Over the past year, SEC has instituted a large number of new capabilities and products which represent a major leap forward in space weather services. New, real-time solar-wind data are allowing SEC to extend the warning time for several geomagnetic storms from 0 minutes (Nowcast) to up to 1 hour in advance. SEC's Rapid Prototyping Center (RPC) has flourished under a Cooperative Research and Development Agreement (CRADA) partnership. In March, 1998, SEC also initiated test products from the Magnetospheric Specification Model (MSM)--the first numerical model being transitioned into operations through the developing RPC mechanism. With its initial infrastructure and concept of operations developed through a CRADA partnership, the RPC is planned to grow into the primary mechanism for transitioning National Space Weather Program sponsored models into operations. In addition to these technical advancements, users will also benefit from 24 hour a day forecaster staffing implemented in October 1998.

Military

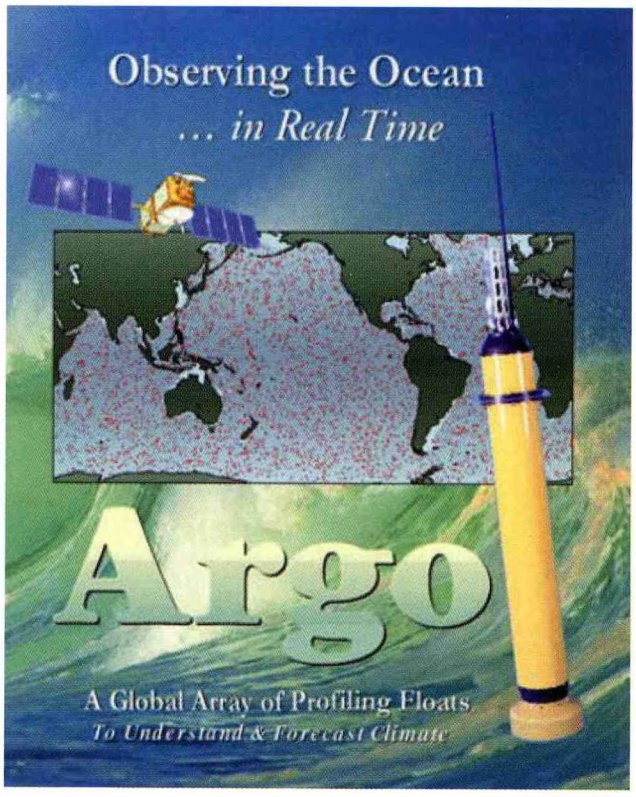
The United States Air Force operates the 55 SWXS in Colorado Springs, Colorado, to provide space weather support to DOD assets. The 55 SWXS operates and maintains the solar observing network with sites at Palehua, Hawaii; Learmouth, Australia; San Vito, Italy; Ramey, Puerto Rico; Sagamore Hill, Massachusetts; and Holloman AFB, New Mexico. The 55 SWXS shares space weather support responsibilities with its civilian counterpart the SEC.

Voluntary Observing Ship (VOS) Program

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

Southern Hemisphere Drifting Buoy Program

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



The TAO/TRITON array consists of approximately 70 ATLAS and TRITON moorings in the Tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the Argos satellite system. Designed to improve detection, understanding, and prediction of El Niño, TAO/TRITON is a major component of the El Niño/Southern Oscillation (ENSO) Observing System, the Global Climate Observing System (GCOS), and the Global Ocean Observing System (GOOS). The array is supported primarily by the United States (NOAA) and Japan (JAMSTEC) with contributions from France (IRD) and Taiwan (NTU). The mooring array is operated and maintained by the TAO Project Office located at PMEL in Seattle, Washington, which has responsibility for project management, operations and logistics. These buoys provide climate researchers, weather prediction centers, and scientists around the world with real-time data from the tropical Pacific. El Niño (the warm phase of the ENSO cycle) is associated with a disruption of the ocean-atmosphere system in the tropical Pacific and has important consequences for weather around the globe. A description and overview of the TAO/TRITON Array is available at *www.pmel.noaa.gov/toga-tao/overview1.html.*

PIRATA (Pilot Research Moored Array in the Tropical Atlantic) is a project designed as an extension of the TAO array into the Atlantic. The purpose of PIRATA is to study ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, interannual and longer time scales. It consists of an array of 12 ATLAS moorings similar to those deployed in the Pacific.

Global Drifter Program

The Atlantic Oceanographic and Meteorological Laboratory, in Miami, Florida, manages the deployment of drifting buoys around the world, deploying some 300 new drifters annually and tracking nearly 700. Using research ships, Volunteer Observation Ships (VOS), and United States Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified operational, they are reported to AOML's Data Assembly Center (DAC). Incoming data from the drifter are then placed on the Global Telecommunications System (GTS) for distribution to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of SST and surface velocity measurements. These measurements are obtained as part of an international program designed to make this data available in an effort to improve climate prediction. Climate prediction models require accurate estimates of SST to initialize their ocean component. Drifting buoys provide essential ground truth SST data for this purpose. The models also require validation by comparison with independent data sets. Surface velocity measurements are used for this validation.

ARGO--Global Array of Profiling Floats--will deploy a global array of 3,000 profiling floats to better understand and forecast climate. ARGO floats will be parked at 1,000m and will profile the water column from the surface to 2,000m. Observations will be made in real-time. Along with satellites, ARGO will initiate the oceanic equivalent of today's operational observing system for the global atmosphere.

NOAA Ship *RONALD H. BROWN*. NOAA recently installed and deployed a 5-cm Doppler precipitation radar to conduct studies of atmospheric processes over the ocean. The system has been shown to not only be effective for studying convective processes but also processes associated with marine stratus clouds. In late 1999, NOAA will install a next-generation shipboard wind profiler on the *RONALD H. BROWN* that is presently in development at the ETL. This profiler will be electronically stabilized (as opposed to the mechanically stabilized systems used on board ships to date) and will employ some new clutter-screen techniques to reduce interferences and obtain profiles much closer to the surface than have been possible to date.

The National Ocean Service (NOS) monitors, assesses, and forecasts conditions in the coastal and oceanic environment to maintain a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. NOS is the primary civil agency within the Federal Government responsible for the health and safety of our Nation's coastal and oceanic environment. NOS acquires water levels, currents, winds, and other physical oceanographic and meteorological data, and distributes these data and circulation predictions as elements of an integrated NOS program (Figure 3-DOC-11). This integrated program provides a comprehensive science-based suite of information products required by the marine transportation community to ensure safe and efficient marine transportation, including the transport of oil and other hazardous materials. Also, NOS provides coastal oceanographic and meteorological products required by the National Weather Service (NWS) to meet its short-term weather and forecasting responsibilities, including tsunami and storm surge warnings/forecasts.

National Water Level Observation Network (NWLON). NOS manages the NWLON, stations located along the coasts of the United States and the Great Lakes, from which water level data, as well as other oceanographic and meteorological data, are collected and disseminated. NWLON provides a number of NOAA and other Federal programs with data and supporting information, such as the NOAA Tide and Tidal Current Prediction program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate and Global Change Program.

An event triggered NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS when the water level exceeds a specified high/low limit or when the rate of change between the standard 6-minute water level values exceeds a specified value.

The NOS Continuous Real-Time Monitoring System (CORMS), now operational, was designed to operate on a 24 hour/7 days a week basis to ensure the accuracy of tide and current observations acquired via the National Water Level and Physical Oceanographic Real-Time System (PORTS™) Programs. CORMS improves the overall data quality assurance of real-time measurements, reduces NOAA's potential liability from disseminating inadequate data, and makes the observations more useful for all applications. CORMS ingests real-time data from all field sensors, determines data quality, and identifies and communicates the presence of invalid or suspect data to real-time users/customers who rely on the data.

Physical Oceanographic Real-Time System (PORTS™). PORTS™ is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS™ measures and disseminates observations and predictions of water levels, currents, salinity, and many meteorological parameters, e.g winds and visibility, needed by the mariner to navigate safely.

PORTS systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. The largest of NOS' existing PORTS™ installations is comprised of over 26 separate instruments. The smallest consists of a single water level gauge and associated meteorological instruments, i.e. winds, barometric pressure, etc.

Regardless of its size, each PORTS™ installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting United States ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill, e.g. EXXON VALDEZ, can cost billions of dollars and destroy sensitive marine habitats critical to supporting

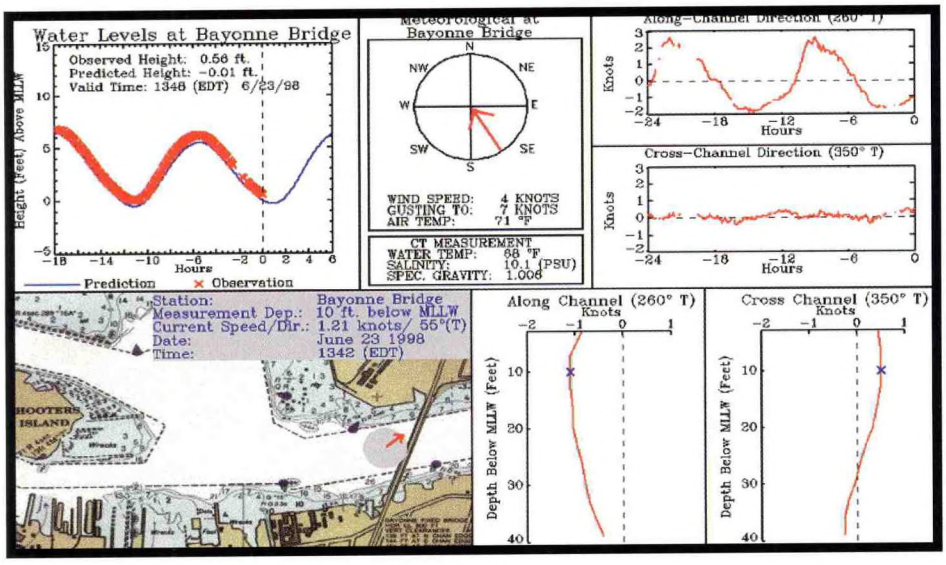


Figure 3-DOC-11. NOS web information of current, water level, and meteorological data for New York/New Jersey Harbor area shipping.

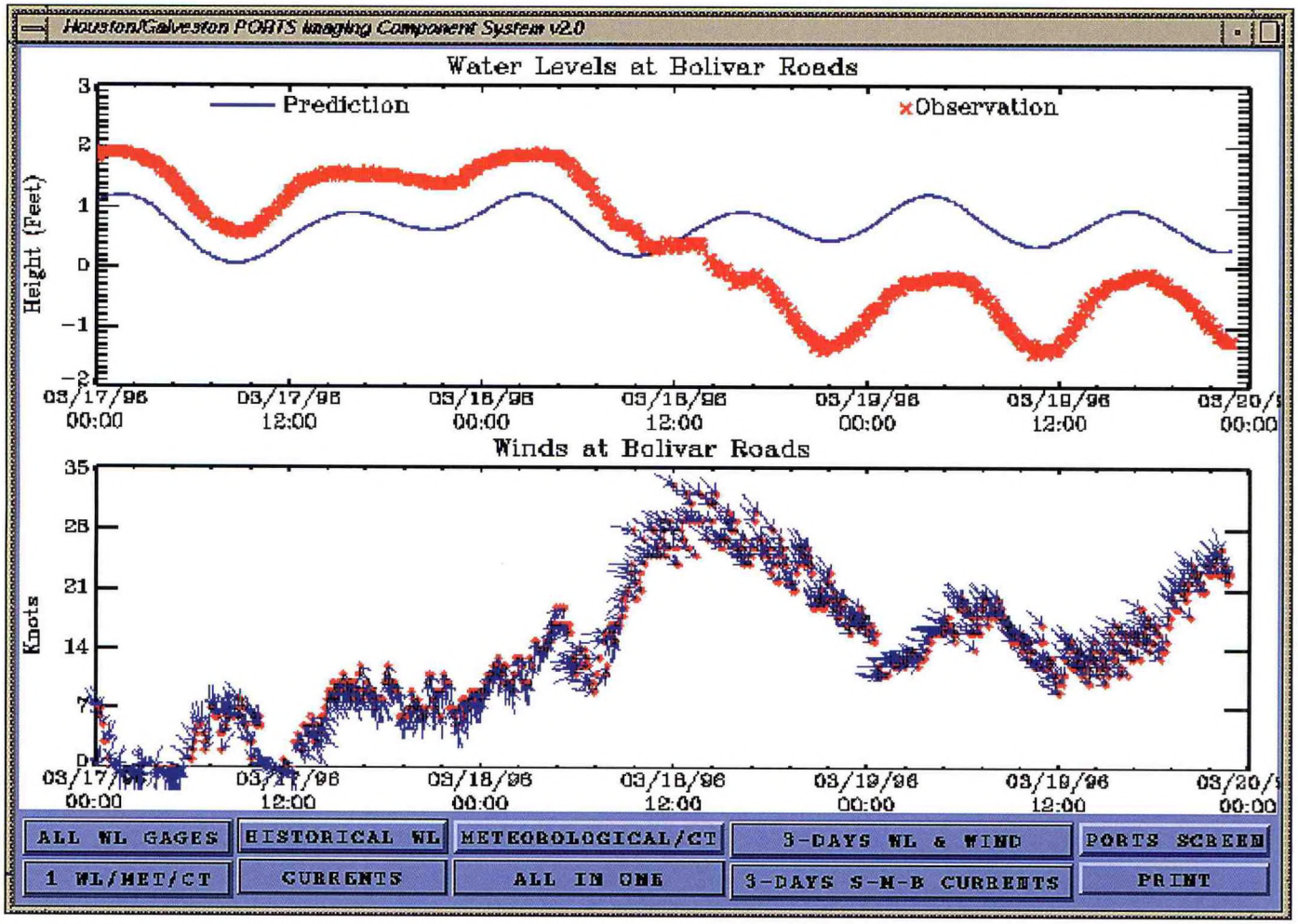


Figure 3-DOC-12. Meteorological influences on coastal water levels. NOS provides information that warns of abnormal conditions, i.e., water levels lowered by the wind.

coastal marine ecosystems. PORTS™ provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur.

An extensible PORTS™ can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS). Also, new developments will enable PORTS™ to incorporate biological and chemical sensor systems and integrate the information with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management.

The integration of PORTS™ technology and numerical circulation models allows nowcasts and predictions of parameters within the boundaries of the models even at locations where physical measurements are not available (Figure 3-DOC-12). The Chesapeake Bay Oceanographic Forecasting System (CBOFS) is an NOS project that provides forecasts of total water level within the Bay in addition to the astronomical tidal prediction. Using wind observations from multiple locations to help force the model, the 1-year root mean square difference between the modeled and observed water level at Baltimore is 9.4 cm.

The Aircraft Operations Center (AOC) provides aircraft support to many NOAA missions, several of them associated with the Natural Disaster Response Initiative (NDRI). In particular, AOC operates a fleet of aircraft to support NOAA's research and development programs to improve weather, marine, and climate services. It provides hurricane reconnaissance and surveillance support to NOAA's National Hurricane/Tropical Prediction Center with its Lockheed WP-3D and Gulfstream IV (G-IV) aircraft as well as flight services to other federal agencies and international programs approved by NOAA's Aircraft Allocation Council. AOC's light aircraft provide aerial photography for nautical and aeronautical charting and living marine resources surveys.

AOC was established in October 1983 through a consolidation of all existing NOAA organizations and elements operating NOAA aircraft. This consolidation was accomplished to achieve a more efficient, more economical and safer operation of NOAA aircraft. Fourteen aircraft, located throughout the United States, are managed by AOC from its home base at MacDill AFB in Tampa, Florida.

NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations, are supported by two WP-3D Lockheed Orion aircraft which carry a full array of state-of-the-art environmental research instrumentation. 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 instrumentation into its automated dated recording systems, and processes and analyzes data sets collected during various field programs.

AOC recently integrated into its operation a new, high-altitude jet, the G-IV, which is used for hurricane surveillance. This aircraft flies in the environment surrounding hurricanes at altitudes up to 45,000 feet. The G-IV dispenses the new GPS dropwindsonde and transmits the resulting profiles of thermodynamic and wind information to the NCEP and the NHC for inclusion in their computer prediction models. Initial estimates of the improvement in hurricane track predictions is between 20 and 30 percent, and these improvements are expected to result in future savings of $10 million or more per hurricane in warning and preparedness costs. With its high-altitude capability, the G-IV is the central focus for additional research leading to improvements in hurricane intensity forecasts. The aircraft will also be used for air chemistry studies and other research in the upper troposphere.

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also provide storm data to the NHC in near real time, transmitting flight level data, dropwindsonde messages, and radar images via its aircraft-satellite data link. The AOC aircraft have primary reconnaissance responsibility for tropical storms and hurricanes in foreign airspace and also augment Air Force Reserve aircraft reconnaissance during particularly active storm periods when tasking requirements exceed available resources.

Land-falling hurricanes, a major subject of the USWRP and NDRI, receive particular attention from AOC aircraft. During the 1998 hurricane season, the G-IV and the WP-3D aircraft flew a combined total of over 400 surveillance, reconnaissance, and research hours on Atlantic storms that made or nearly made landfall in the continental United States. Joining with the AFRES and NASA aircraft, the three NOAA planes participated in the first multi-agency hurricane research experiment since STORMFURY, a hurricane modification project that took place in the early to mid-70's. The Convection and Moisture Experiment III (CAMEX-3) experiment focused on the measurement of cloud moisture using a variety of space-borne and aircraft mounted remote sensors.

DEPARTMENT OF DEFENSE WEATHER PROGRAMS

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

UNITED STATES AIR FORCE

METEOROLOGICAL SERVICES

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

Air Force Weather (AFW) Organization. AFW has reengineered to mirror the three levels of military operations--strategic, theater (operational), and tactical. The Air Force Weather Agency (AFWA), a field operating agency (FOA) reporting to HQ USAF/XOW, provides strategic-level weather support (global and synoptic-scale) for their worldwide customers, as well as fulfills some unique mission requirements (discussed later). HQ AFWA, located at Offutt AFB, Nebraska, has two subordinate centers: the Air Force Combat Climatology Center (AFCCC) at Asheville, North Carolina and the Air Force Combat Weather Center (AFCWC) at Hurlburt AFB, Florida. Space environmental support is provided by the 55th Space Weather Squadron (55 SWXS) at Schriever AFB, Colorado, which recently transferred organizationally from Air Force Space Command to AFWA. Along with this organizational transfer, part of the space environment mission will migrate to HQ AFWA at Offutt AFB during 2000-2001. Nine Operational Weather Squadrons (OWSs) serve in direct support of overseas theater CINC and/or Numbered Air Force (NAF) operations. Each OWS is designated as the forecast agency for a specific geographical Area of Responsibility (AOR) (Figure 3-DOD-1) in concert with their supported NAFs or Theater's AOR. CONUS OWSs are also responsible for CONUS regional weather support. They produce and disseminate terminal forecasts, weather warnings and advisories, planning and execution area forecasts, and other operational products to Combat Weather Teams (CWTs). The CWTs, located on the base and post level, take and disseminate local observations and provide mission-tailored forecasts and briefings based on centrally produced guidance. AFW personnel enhance the unique global capability of ground and aerospace military operations, while indirectly assisting civil aviation, by providing flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

Weather Data Collection integrates weather radars and meteorological sensors into a single meteorological sensing and instrumentation approach for battlefield and in-garrison operations. Current and future programs include: Observing System 21st Century (OS-21), Tactical Weather Radar (TWR), and Small Tactical Terminal (STT). Observation and sensing of the space environment are discussed in the Space Environmental Services section.

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

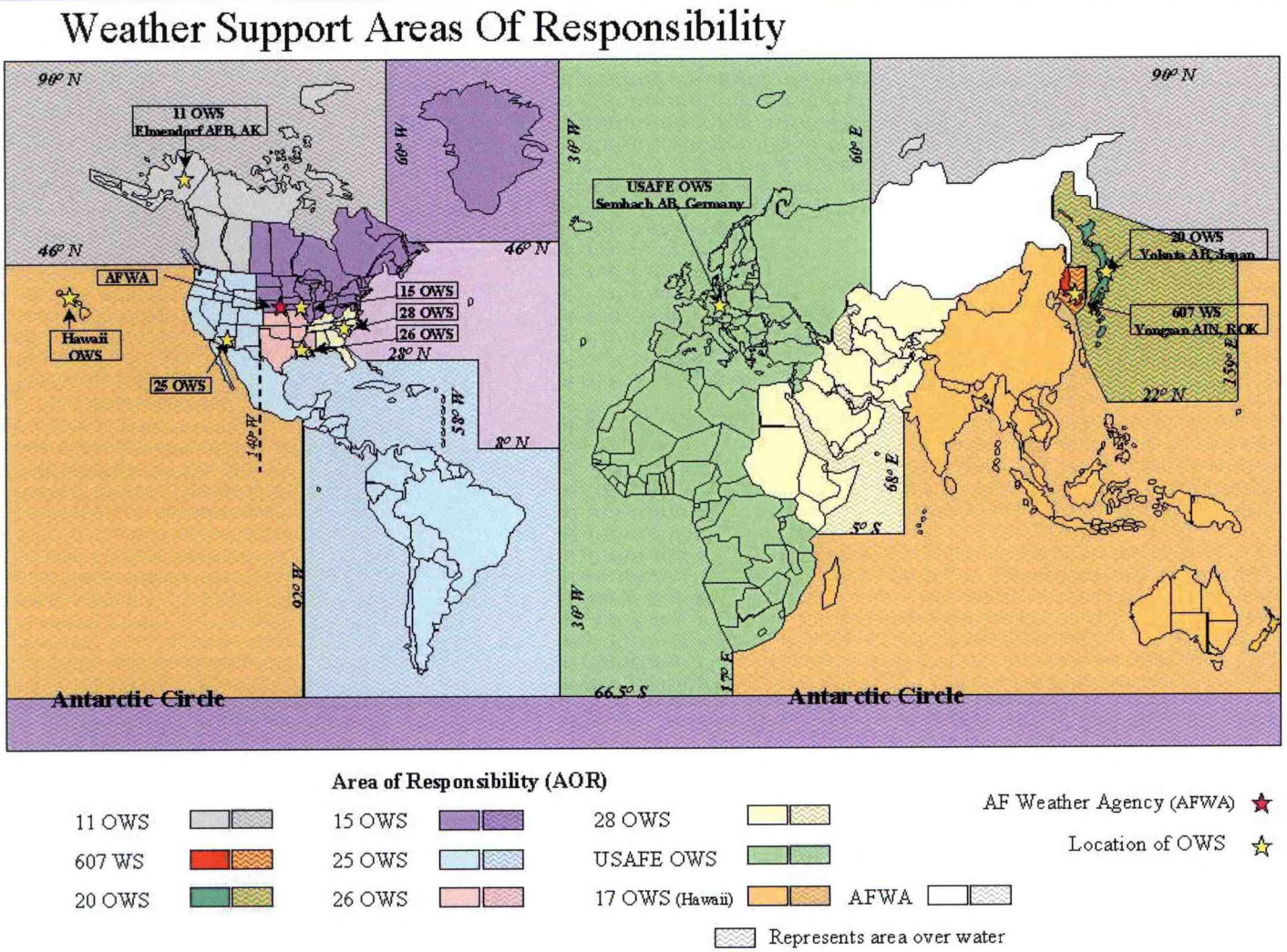


Figure 3-DOD-1. Areas of Responsibility for Air Force Weather's Operational Weather Squadrons.

the world, via the Automated Weather Network (AWN). Upper air observations provide vital input for numerical weather analysis and prediction. United States and foreign rawinsonde reports are primary sources and are supplemented with military and civilian pilot reports. The OS-21 program will provide a much needed state-of-the-art life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: Fixed, Deployable, Remote, Manual, and Upper Air. The Manual section is intended for tactical operations and will continue upgrades begun under the Manual Observing System (MOS) and Tactical Meteorological Observing System Modification (TACMET MOD) programs. AFW purchased commercial off-the-shelf Remote Miniature Weather Sensors to provide accurate real-time weather information from forward unmanned locations to support Kosovo operations (Figure 3-DOD-2). OS-21 will continue to expand this capability.

Weather radar is a principal source of information for providing severe weather warnings. Within the CONUS, AFW uses the WSR-88D, procured through the NEXRAD Joint System Program Office. It is operated and maintained by DOD, NOAA, and FAA within the CONUS and by the Air Force overseas. The WSR-88D system incorporates the latest technological advances in Doppler radar, data processing, communications, and display, and continues to be modernized to improve reliability and maintainability. Tactical Weather Radars (TWR) are used to support contingency operations. The TWR program supports worldwide military operations by providing tactical/deployable Doppler weather radar capability, replacing existing radars at deployed locations and at fixed locations overseas.

The Air Force manages the Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, and is the most important single source of global weather data used for combat support. On-board sensors provide AFWA, 55 SWXS, and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, elec-

trically charged particle fluxes, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional image and mission-sensor data to DOD land-based and shipborne terminals located worldwide.

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

The STT provides worldwide tactical users with a survivable "first-in" source of meteorological satellite data, processed by small, portable terminals in forward areas of conflict. These terminals process remote-sensed visual/thermal imagery, from both polar orbiting and geostationary satellites, and other non-imagery weather data to support combat forces.

Analysis and Forecasting. The AFWA is the primary production center for providing weather analyses and forecasts for Air Force and Army operations. AFWA uses a networked computer system and an interactive graphics and imagery system to implement a "build-and-apply" concept. Worldwide weather data are relayed to AFWA and blended with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. AFWA also provides backup for the National Weather Service (NWS) Storm Prediction and Aviation Weather Centers.

AFWA has organized forecast operations to achieve greater flexibility and focus production on its primary customers. Forecasts are generated in the agency's Global Weather Center Division, which consists of four production branches: Forecast Production, Special Support Operations, National Programs Operations, and Satellite Applications.

The Strategic Section of the Forecast Production Branch produces tailored worldwide meteorological analyses and forecasts in support of aviation customers. The branch also provides forecasts of CONUS low-level aviation hazards. The CONUS Severe Forecast Section provides specific point weather warnings for Air Force and Army installations in the CONUS and hot backup to Aviation Weather Center and Storm Prediction Center. The American Forces Network Section provides worldwide, broadcast-quality public weather services and planning forecast support through the American Forces Television Network to DOD personnel and family members stationed overseas.

The Special Support Operations Branch (SSOB) provides worldwide mission-tailored forecasts to Joint Special Operations Forces (SOF). The branch acts as a clearinghouse for unique data requests from the SOF customers; provides end-to-end targeting support to unified command, component, or national customers; produces long-range (4-8 day) forecasts to unified command, component, or national customers; and supplies the Nation's reconnaissance cloud-free forecast products. SSOB is also in the process of accepting portions of the space-forecast mission from the 55 SWXS.

The National Programs Operations Branch provides weather support for classified National Programs directed by the Secretary of the Air Force. The branch produces detailed global cloud analyses to update and refine the Real Time Nephanalysis (RTNEPH) database. The branch identifies and documents weather service requirements and initiates actions to ensure Sensitive Compartmented Information (SCI) and Special Access Program (SAP) weather support needs are met. They serve as the focal point for AFWA SAPs; ensure National Program and other SCI and SAP support requirements are integrated into AFWA programs; monitor and evaluate accuracy and timeliness of centralized weather services to National Programs; and interface with the DOD and national intelligence community regarding weather services and exploitation of weather information.

The Satellite Applications Branch provides rapid response tailored METSAT

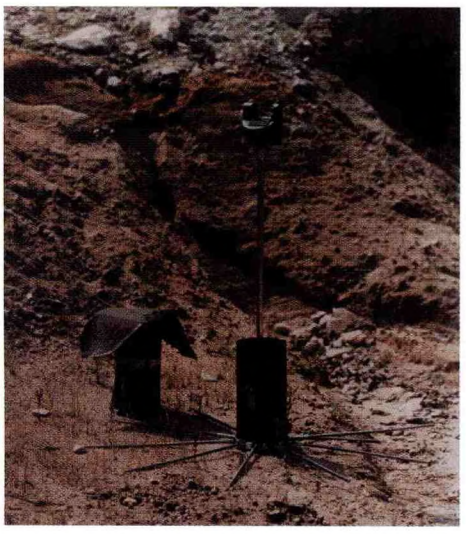


Figure 3-DOD-2. AFW's remote miniature weather station.

imagery and evaluation for DOD contingency mission support. The branch produces regional snow and ice cover analyses to update and refine the Snow Depth (SNODEP) database; and generates automated METSAT imagery products for AFWIN/ SAFWIN distribution to DOD customers. The branch also tracks and classifies tropical cyclones (METSAT analysis) for the DOD Joint Typhoon Warning Center (JTWC) and other United States Tropical Cyclone Warning Centers; provides hot back up for JTWC satellite operations; monitors operational status; and evaluates quality of imagery ingested at AFWA. They coordinate corrective actions; maintain, modify, and develop new capabilities to display and visualize satellite imagery data on workstations; infuse state-of-the-art techniques into improved imagery analysis ensuring high quality customer products; serve as AFW focal point on technical issues regarding METSAT imagery utilization; and interface with the DMSP System Program Office, Air Force Space Command, and other DOD and governmental agencies on METSAT data exploitation issues.

As the space weather mission transitions from 55 SWXS to HQ AFWA, a space weather operations branch at AFWA will provide worldwide general and tailored analyses, forecasts, advisories, and warnings for space weather phenomena that can affect military operations and National Programs activities. The branch will provide products for agencies from all DOD Services using space weather measurements from a variety of ground- and space-based sensors. Data sharing and forecast coordination is performed with the NOAA Space Environment Center (SEC) in Boulder, Colorado.

On-going modernization initiatives at AFWA include the Cloud Depiction and Forecasting System (CDFS) II, Global Theater Weather Analysis and Prediction System (GTWAPS), Space Weather Analysis and Forecasting (SWAFS), and modernization of the communications and data processing infrastructure including a significant increase in the data base capacity. CDFS II will make major software and hardware modifications at AFWA to upgrade the weather satellite data processing, cloud depiction and forecasting, and classified weather support functions for operational customers and National Programs, providing a capability that cannot be met with the current system. The GTWAPS program is nearing completion and this year's efforts will allow further merger of the strategic and theater level forecasting systems at the weather centers and OWSs. The key software component of the GTWAPS program is a theater analysis and forecast model--Mesoscale Model version 5 (MM5), which provides highly accurate, fine-scale forecast data. SWAFS will integrate additional space weather data sources and execute next-generation space weather models in support of DOD and National Programs operations (Figure 3-DOD-3).

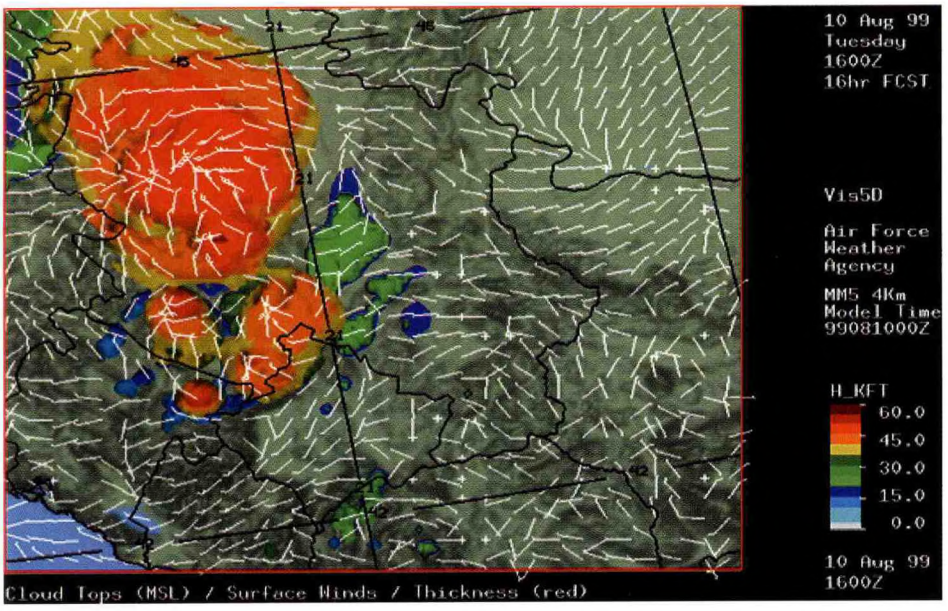


Figure 3-DOD-3. Visualization of MM5 Forecast over the Balkans.

Product Tailoring/Warfighter Applications. AFW organization was designed such that the OWSs and CWTs take the products created by the higher levels and add additional details, tailored to the specific region or mission requirement. The Forecasting System 21st Century (FS-21) program is the vehicle for providing necessary computer hardware and software at both the OWSs and CWTs. The OWS Production System, Phase 2 (OPS-II), is the backbone of the OWS production system. It's a hybrid system of databases, servers, and work stations, which provides the computer hardware and software necessary for OWSs to produce and disseminate forecast products to CWTs.

The New Tactical Forecast System (N-TFS) provides in-garrison and deployed CWT personnel the meteorological tools necessary to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and Air Force operational, command and control, and support forces worldwide. N-TFS provides weather personnel the ability to use the same system in "peace and war", thus providing a robust "first in" and sustainment weather forecast capability to combat weather units worldwide. Additionally, N-TFS ingests data from

Air Force observing systems and observations from indigenous sources. Data from the N-TFS, combined with satellite imagery from the STT, provide the essential capability required for deployed weather units to meet operational mission requirements.

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

Dissemination. The Air Force communications system uses a variety of media to meet the dissemination needs of its worldwide customer base. Asynchronous Transfer Mode (ATM) fiber optic networks are used to distribute high-resolution satellite imagery and forecast data from global numerical weather prediction models between large DOD and civilian processing centers. Commercial T-1 circuits provide a subset of this data to new theater and regional forecast facilities. Forecaster-developed products and gridded data sets are distributed from HQ AFWA via the Communications Front-End Processor to base and post weather stations using dedicated 9600-baud circuits. These dedicated circuits are now augmented by, and will eventually be replaced by commercial Kμ-band broadcast satellites over the CONUS, Europe, and the Pacific. The broadcast satellites now provide tailored satellite and WSR-88D imagery to the base and post weather stations at both fixed and deployed locations.

Alphanumeric data including synoptic, upper-air, and pilot reports are collected and distributed via the AWN. The AWN is a collection of dedicated circuits ranging from 74-baud to 56kbps linking DOD, national and international facilities worldwide. Data is also received from DOD-operated High Frequency (HF) radio receiver sites strategically positioned around the globe to intercept weather broadcasts. These broadcasts originate from nations that do not routinely make data available through World Meteorological Organization (WMO) channels. The Automatic Digital Weather Switch at Tinker AFB, Oklahoma receives alphanumeric weather data and Notices to Airman (NOTAMs), parses them according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are redistributed to end users over: (1) the same dedicated circuits, (2) the DOD's Non-secure Internet Protocol Network (NIPRNET), and (3) HF and satellite broadcast facilities. End-user systems include the Automated Meteorological Information System (AMIS), Meteorological Information Standard Terminal (MIST) and small computers using a variety of alphanumeric display packages.

AFW utilizes the NIPRNET to host the Air Force Weather Information Network (AFWIN) and the Military Aircrew Information System (MAIS). AFWIN provides worldwide access to numerical model forecast graphics, satellite imagery, and text bulletins. MAIS was designed to accept aircrew mission parameters and provide weather data for the takeoff base, route of flight, and destination.

Unique Support Requirements. A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers, as well as operational units. To fulfill this requirement, designated AFW personnel serve as part of the working staff of operational Air Force, Army, and joint force units. In this capacity, AFW personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. Support is tailored to the needs of weapon systems being developed or used, command and control systems, Army firing units, research, development and evaluation, testing, training and deployment of military forces, and contingency operations. This effort helps ensure that Air Force, Army, and joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission specific requirements.

The Army weather support mission is completely integrated into the Air Force's overall mission concept. The Army trains and educates Air Force personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. AFW units are aligned and integrated with the Army intelligence organization. Weather products are tailored to be directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observer

support to all command levels identified above. The Army Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARTYMET) program augment the Air Force observations in the tactical environment.

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

The Air Force and Navy operate JTWC, which moved to Hawaii in 1999. JTWC provides tropical cyclone warning services to DOD units and other United States subscribers in the area west of 180 degrees longitude to the East Coast of Africa in both hemispheres.

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

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

AFCCC provides climatic data and specialized studies to support the Air Force, Army, and other government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects environmental data from AFWA and then sorts, checks, stores, and employs these data to produce tailored products. AFCCC is co-located with the National Climatic Data Center to facilitate cooperation and data exchange. AFCCC typically collects, quality assures, and applies worldwide surface and upper air observations, a three-dimensional (3D) cloud analysis extracted from meteorological satellite imagery (Real-time Nephanalysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

AF/XOW is the DOD Modeling and Simulation Executive Agent (MSEA) for the Air and Space Natural Environment (ASNE). The director executes his responsibilities through the Office Chief co-located at the AFCCC. The Executive Agent is responsible to ensure modeling and simulation developers and users have environmental models, algorithms, and data to represent the air and space environment rapidly, thoroughly, accurately, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, re-use, and confidence.

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

SPACE ENVIRONMENTAL SERVICES

The 55 SWXS is the DOD focal point for operational space environmental support and the execution of this mission is transferring to HQ AFWA during 2000-2001. The 55 SWXS includes a forecast operations center at Schriever AFB as well as six solar observatories located throughout the world. Additionally, 55 SWXS participates with NOAA in the joint operation of the SEC.

Many DOD systems are affected by space weather phenomena that occurs in the troposphere, stratosphere, mesosphere, thermosphere, ionosphere, and magnetosphere. The space weather processes that occur in these near-Earth environments are greatly influenced by processes originating on the Sun and in interplanetary space and by the interactions between the solar phenomena (radiation and/or electrically-charged particles) and the Earth's upper atmosphere and magnetic field. Collectively, these processes lead to space weather conditions in the near-Earth environment which can adversely affect operations. The 55 SWXS provides general and tailored products directly related to the space weather effects on DOD communications, surveillance/intelligence collection, satellite operations, navigation, and space tracking and warning systems.

Space weather products and/or specialized services include:

- Ionospheric conditions (electron densities and disturbances) and their potential effects on communications, intelligence-collection, precision navigation, space tracking, detection/warning operations,

and manned space flight (Figure 3-DOD-4).

- Magnetospheric conditions (charged-particle fluxes) and their potential effects on satellite operations, to include after-the-fact assessments of whether space weather conditions caused anomalous behavior or failures experienced by satellite components and sub-systems.
- Thermospheric conditions (atmospheric densities) and their potential effects on satellite drag and satellite launch calculations.
- Tropospheric, stratospheric, and mesospheric conditions (extremely energetic particles, radio wave radiation and interference, magnetic field disturbances) and their potential effects on high-altitude flight, communications, intelligence collection, and space tracking and warning.
- Solar conditions (radiation and/or electrically charged particle fluxes due to various solar phenomena) and their potential effect on the near-Earth environment.
- Immediate response advisories and warnings of all conditions described above which may have significant effects on one or more military operations.

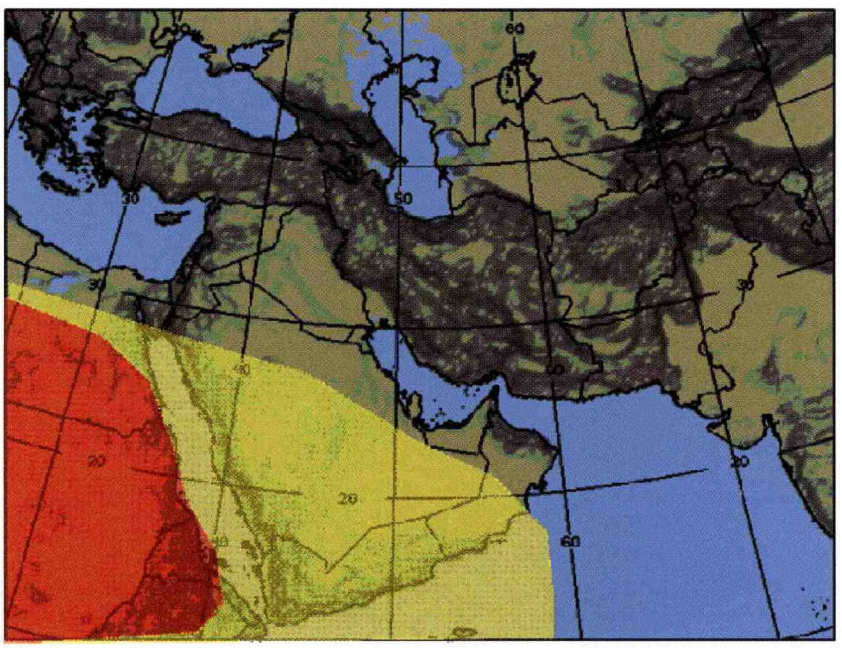
Sources of Space Environmental Data. A variety of ground- and space-based space weather data is available to forecasters providing space weather support.

The 55 SWXS operates a network of solar optical and radio telescopes at Sagamore Hill, Massachusetts, Ramey, Puerto Rico, Holloman AFB, New Mexico, Palehua, Hawaii, San Vito, Italy, and Learmonth, Australia. These systems provide observations of solar phenomena at optical and radio wave wavelengths.

A worldwide (primarily Northern Hemisphere) network of ground-based ionosondes and other sensors provide ionospheric data. AFW manages the automated Digital Ionospheric Sounding System (DISS) to provide ionospheric measurements. The Jet Propulsion Laboratory also operates a global network of sensors that provide ionospheric data. A network of magnetometers is operated by the United States Geological Survey (USGS). The USGS data provides indirect measurements of the strength of ionospheric and magnetospheric electric currents which create their own magnetic field that is superimposed upon the Earth's magnetic field.

The Geostationary Operational Environmental Satellites (GOES) vehicles provide real-time solar X-ray and electrically charged energetic particle and geomagnetic data. This data is made available through the SEC. DMSP, NOAA, and other DOD geostationary satellites provide additional energetic electrically charged particle data in low-Earth and geosynchronous orbits. Other space-based data is available from NASA and other agencies. For example, real-time solar wind data is provided by the NASA Advanced Composition Explorer satellite.

A number of additional sensors or improvements to existing space weather sensors are planned. A Solar X-Ray Imagers (SXI) will be flown beginning



Regions with no annotation represent conditions unlikely to affect UHF SATCOM

Regions annotated in yellow represent disturbed conditions that can degrade UHF SATCOM operations

Regions annotated in red represent severely disturbed conditions that can significantly degrade UHF SATCOM operations

For assistance in interpreting/applying this product for theater or local operations, press the UHF Satellite Communications "Help" key on the AFWIN space menu.

Figure 3-DOD-4. 55 SWXS operational forecast identifies locations where Ionospheric conditions will impact UHF SATCOM applications.

on the next GOES satellite launched. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. AFWA's Solar Radio Burst Locator (SRBL) is projected to be operational in 2001 and will provide radio wave measurements of the Sun while also mapping (locating) certain solar phenomena that would otherwise be unseen by optical telescopes during periods of cloud cover. AFWA has additional improvements scheduled for the optical telescopes (known as ISOON) as well as to various ionospheric sensors.

Various space weather models are used to specify current solar or global characteristics of space weather where observations are not available and to assist forecasters in generating forecasted conditions. These models use available observations and are climatological-based or physics-based in calculating their output. Improved models are planned under the SWAFS program during the next five years. A new initiative known as the Community Coordinated Modeling Center at HQ AFWA will serve as a proving-ground for new space weather model development.

The consolidation of the space weather and terrestrial weather strategic center functions under HQ AFWA at Offutt AFB will enable AFWA to provide seamless aerospace weather support to DOD forces, reduce USAF infrastructure costs, streamline customer support process, and improve space weather services. Two new space weather support units were established to support the Space Command mission. One of these new units is Detachment 1, Space Operations Group whose mission is to support the Aerospace Operations Center at Vandenberg AFB, California. The other unit is the 50th Operations Support Squadron, Weather Flight. This unit will support space missions controlled from Schriever AFB, Colorado, one portion of the current mission of the 55 SWXS.

SUPPORTING RESEARCH

The overarching objective of the Air Force meteorological and space environmental R&D program is to provide system designers and operational weather support personnel with the technology tools to gain and maintain the advantage over a potential adversary. Documented R&D requirements in the atmospheric sciences are articulated in the AFW Mission Support Plan and in the Mission Area Plans of the Air Force major commands. More specific guidance is found in Technical Needs, documented in the associated Weather Development Plan. Space environment R&D is targeted to meet the DOD's space weather requirements as summarized in the National Security Space Architect's Space Weather Architecture Study and the associated Implementation Plan.

The responsibility for conducting and managing environmental sciences R&D (including meteorology and space weather) resides with the Air Force Research Laboratory (AFRL) Battlespace Environment Division located at Hanscom AFB, Massachusetts. Its applied research program in meteorology is focused to emphasize weather prediction methods, cloud modeling and simulation, weather impact decision aids, and optical turbulence for airborne laser applications. In space weather, the AFRL research program focuses on ionospheric impacts on RF systems, space particle specification and forecast, solar disturbance prediction, and neutral density effects on LEO spacecraft. Working closely with SMC/CI under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include space environment sensors on the DMSP spacecraft, state-of-the-art ground-based scintillation detectors, total electron content sensors, DISS, ISOON, and the Operationalized Space Environment Network Display (OP-SEND) suite of web-based products. AFRL also conducts customer-supported R&D for NPOESS, the Defense Modeling and Simulation Office (DMSO), the National Reconnaissance Office (NRO), the Ballistic Missile Defense Office (BMDO), the DOD High Performance Computing Modernization Office (HPCMO), and NASA.

Weather Prediction Methods. R&D efforts in this area focus on the development of aviation-mission-impact-variable algorithms to be applied operationally at the AFWA. Multivariate diagnostic algorithms, applicable to data provided by global and theater-scale numerical weather prediction models, have been developed to infer cloud characteristics (layered and total cloud amount, bases, tops, ceiling), aviation hazards (icing, turbulence, and thunderstorms) and surface conditions (present weather and horizontal visibility). The cloud, icing, and turbulence algorithms have been implemented at AFWA where they are being evaluated operationally as part of the GTWAPS program. The present weather, thunderstorms, and horizontal visibility algorithms are awaiting evaluation testing at AFWA. A Weather Technology Unit (WTU) has been established to provide weather research and development support to AFWA through technique development, technology transition, and technical assistance. The WTU is currently a four person effort with one AFRL researcher located on-site at AFWA. WTU tasks focus on several near- and mid-term weather prediction capabilities. The AFRL diagnostic cloud forecast algorithm is being transitioned into AFWA operations. A theater-scale cloud analysis procedure is being developed capable of specifying cloud water content in the initial conditions of the AFWA theater-scale numerical

weather prediction model--MM5. Contrail analysis and prediction schemes are nearing completion, comparing the skill of the AFWA operational contrail scheme with a statistical model developed from contrail field experiments. An extensive evaluation of the MM5 model is underway as a forecast source from which optical turbulence models can diagnose conditions adverse to the Airborne Laser (ABL) mission. Finally, a 3 year project has begun that will demonstrate the feasibility of executing a mesoscale four-dimensional variational data assimilation procedure in operational timelines on a massively parallel processing computer.

Cloud Modeling and Simulation. The Cloud Scene Simulation Model (CSSM) has become the cornerstone for in-house, service-sponsored projects to provide physically and radiometrically accurate cloud simulations. These projects provide capabilities needed in the Modeling and Simulation (M&S) community for consistent, physically based synthetic atmospheres to drive war-gaming, training, system design studies, etc. The AFRL focus this past year has been in areas such as: (1) transitioning a cloud/NWP model data fusion approach to the exploitation of National Technical Means data, (2) designing an extension of the CSSM to support campaign-level simulations in infrared wavebands, and (3) performing a military utility analysis for the National Polar-orbiting Operational Satellite System (NPOESS). CSSM has reached a point of maturity where it is routinely used in war-gaming demonstrations and exercises (for the Air Force and Navy) and in the conduct of data impact/sensitivity.

Weather Impact Decision Aids. A major focus of the Air Force's investment in meteorology R&D deals with the development, evaluation, and implementation of weather impact decision aids (WIDA) which predict the impact of weather and other environmental factors on the performance of electro-optical (IR, NVG, laser, TV) systems. This is a joint program led by AFRL with Navy NRL and Army ARL participation. WIDA products are used to support precision-guided munitions, night-vision, surveillance, and navigation systems. There are three products under development in the WIDA program. Three of the four products will provide unit-level weather impact support for mission execution. The mission execution products are: (1) infrared (IR) Target-scene Simulation Software (IRTSS), (2) Night Vision Goggle (NVG) Operations Weather Software (NOWS), and (3) Target Acquisition Weather Software (TAWS). The fourth, Weather Automated Mission Planning Software (WAMPS), incorporates WIDA products described above into Air Force command and control systems from the force to the unit-level. The products combine global terrain and features, target signatures, electro-optical (EO) sensor performance models, and meteorological and operational planning data to provide decision-makers and warriors with quantitative impacts of weather on their systems as well as EO scene visualization tools for environmental situational awareness. NOWS 5.2 was transitioned for operational use in June 1999 and TAWS V1.1 in December 1999. IRTSS will transition to AFWA in September 2000.

Atmospheric Optical Turbulence. EO and laser systems are adversely affected by optical distortions induced by atmospheric temperature or refractive turbulence. As the sophistication grows in current and next generation military systems, the requirement for more detailed knowledge of the fine scale (meters or less) atmospheric behavior also grows. The Airborne Laser (ABL) program is one such system. Since the meteorological conditions that produce turbulence vary, the performance of such systems varies. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. Measurements are performed by a balloon-borne turbulence sensor which is mated to a standard radiosonde. This program has produced data and empirical models that are the basis for ABL system specification. Balloon-borne measurements are now being made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum is also sampled using balloon-borne high-bandwidth sensors. As part of an international program, aircraft measurements of temperature and velocity turbulence have been made in different locales worldwide. Horizontal measurements by the aircraft augment the vertical profiling by balloons.

Empirical seasonal models have been developed for different theaters which are in widespread use. Data collected are now being used to develop models of vertical and horizontal structure of turbulence in the troposphere and stratosphere. These models are correlated with meteorological sources of gravity waves such as jetstreams, fronts, mountains, and thunderstorms. This modeling is closely coupled with work on the generation, propagation, and breakdown of gravity waves. Work is also underway to predict optical turbulence based on theater-scale numerical weather prediction models (NWP) used with optical turbulence parameterizations. This forecasting effort is being tested and evaluated for a number of locations around the world. The ultimate objective of these efforts is to develop models that allow the forecasting and prediction of ABL system performance.

Ionospheric Impacts on RF Systems. Irregularities in the Earth's ionosphere driven by solar and geophysical activity

cause problems for DOD C³I, navigation, and surveillance systems. AFRL's research program focuses on the specification and forecasting of global electron density profiles and ionospheric scintillation. In the scintillation arena, AFRL has developed the Scintillation Network Decision Aide (SCINDA), a set of ground-based sensors and quasi-empirical models that provide real-time alerts and short term (<1 hour) forecasts of scintillation impacts on UHF satellite communication in the Earth's equatorial regions. Work is underway to extend the SCINDA ground station network and construct an L-Band scintillation model for application to GPS navigation links. The Communication/Navigation Outage Forecast System (C/NOFS) satellite is being developed by AFRL in collaboration with the Naval Research Laboratory to provide 4-6 hour forecasts of scintillation outages and is scheduled for launch in FY 2003. AFRL is responsible for development and calibration of the SSIES plasma density instrument and the SSM magnetometer currently flying on the DMSP satellites, to include the development of automated data processing algorithms. A program to comprehensively validate the Parameterized Real-time Ionospheric and Specification Model (PRISM), currently being used by 55 SWXS to specify global electron density profiles, is underway as are upgrades to ground-based sensors to measure total electron content along ground-to-satellite links and electron density profiles of the lower ionosphere. Basic research efforts are focused on creating physics-based models needed to forecast global electron density profiles, scintillation structures, and neutral density variations affecting satellite drag.

Space Particle Specification and Forecast. Energetic particles in the near-Earth space environment pose hazards to DOD spacecraft such as single event microelectronic effects induced by MeV cosmic ray ions, deep-dielectric charging induced by MeV electrons in the outer Van Allen belt, and spacecraft frame charging and discharging induced by keV electrons created in geomagnetic storms. AFRL has a robust program to develop and fly the Compact Environment Anomaly Sensor (CEASE) which is a small, lightweight, low-power sensor that provides alerts and warnings of space particle hazards to satellite operators increasing situational awareness and decreasing anomaly resolution time. CEASE can also provide scientific level data, given sufficient telemetry, which can be used to develop climatological models or drive real-time specification models. The Relativistic Electron and Energetic Proton Experiment (REEPER) is being built to resolve the energy spectra of the highest energy electrons and protons found during large geomagnetic storms and is manifest on NASA's Inner Magnetosphere Explorer (IMEX) satellite scheduled for launch in FY 2003. AFRL is responsible for the development and calibration of the SSJ4 electron and proton sensor flying on the DMSP satellites. Automated data reduction algorithms and tailored auroral boundary products using the SSJ4 data are also created. Complementing the sensor program, AFRL develops, validates, and transitions models of the aurora, radiation belts, and magnetospheric plasma to meet the needs of the acquisition, operations, and modeling and simulation communities. The AF-GEOSpace code comprises many of the models developed by AFRL and its collaborators, including quasi-empirical models constructed from DMSP, CRRES, and APEX satellite data and the Magnetospheric Specification Model (MSM), and serves as a 'kernel' for transitioning tailored products to operations. Physics-based models for forecasting the distributions of energetic particle in the radiation belts are the primary focus of basic research work.

Solar Disturbance Prediction. The Sun ultimately drives all of space weather. Any attempt to forecast direct solar effects, such as solar proton or HF absorption events, or obtain long lead-time forecasts (several days) of geomagnetic and ionospheric events requires the specification and forecast of solar activity. AFRL maintains a research group at the National Solar Observatory, Sacramento Peak, New Mexico dedicated to advancing ground and space based solar physics and applying it to meet DOD solar forecasting needs. The Improved Solar Optical Observing Network (ISOON) is being built for SMC/CI and AFWA by AFRL to replace the current USAF SOON telescope system. When the first of four units becomes operational in FY 2001 it will improve the optical resolution and image cadence beyond what is available with SOON, reduce operating costs, and expand the magnetic field determination capabilities. Applications are also being developed to use white-light solar surface flow observations and magnetograms to obtain 1-2 hour forecasts of solar flare events that can eventually be applied to ISOON data. An advanced space-based imager designed to detect coronal mass ejections (CMEs) all the way from the sun to the Earth is being built by AFRL and is scheduled for space-test in early FY 2002 on the CORIOLIS satellite. If successful the Solar Mass Ejection Imager (SMEI) will provide 1-3 day forecasts of geomagnetic storms with a high degree of accuracy. Current operational solar shock forecast models (i.e. the Interplanetary Shock Propagation Models (ISPM) and the Shock Time of Arrival Model (STOA)) are being extensively validated at AFRL and the necessary models of irregularities in the solar wind needed to improve the models are being developed.

PROGRAM OVERVIEW

The United States Navy has the unique military requirement to assess meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations - anywhere in the world, at anytime. Naval METOC must support world-wide naval, joint, and combined operations, anytime and anywhere, with the focus predominantly on areas outside of the contiguous 48 states (Figure 3-DOD-5). METOC support begins by measuring the battlespace physical environment and culminates with safe, effective weapons systems and sensor employment. Developing METOC forecasts and determining potential effects on weapons system information requires:

- the collection of data through tactical and dedicated sensors (including satellites);
- fusion and analysis of atmospheric and oceanographic phenomena; and
- meteorological information in tactical decision aids and mission planning systems.

The Chief of Naval Operations, through the Oceanographer of the Navy (CNO(N096)), sponsors operational Navy METOC services and related research and development (R&D). The Navy provides meteorological services for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. The Oceanographer of the Navy sponsors programs in four closely related disciplines to provide worldwide, comprehensive, integrated weather and ocean support--meteorology, oceanography, geospatial information and services, and precise time and astrometry. All are used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, and to provide a decisive tactical or strategic edge by exploiting the physical environment.

Research and development is conducted by warfare centers, laboratories, and systems commands, through sponsorship by the Chief of Naval Research and the Oceanographer of the Navy. The Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARSYSCOM) are the primary activities, in addition to various universities, industry partners, and organizations under Navy contract. NRL detachments are collocated with the Fleet Numerical Meteorology and Oceanography Center in Monterey, California, and with the Naval Oceanographic Office at Stennis Space Center, Mississippi. The SPAWARSYSCOM METOC Systems Program Office (PMW-185) is Navy's single program manager for METOC system development and acquisition.

Figure 3-DOD-5. Navy METOC's global organization

METEOROLOGICAL SERVICES

UNITED STATES NAVY

Operational support within the Navy is provided by elements of the Naval Meteorology and Oceanography Command (NAVMETOCCOM). Navy METOC activities are involved in worldwide collection of observations ashore, afloat and through remote sensors, and in the assimilation and processing of these observations on a global basis to support analysis and forecasting throughout the world.

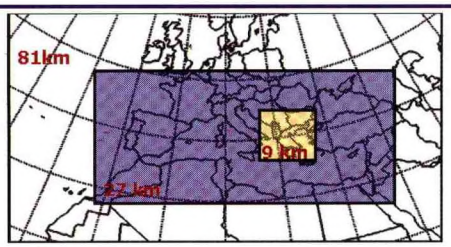
The Fleet Numerical Meteorology and Oceanography Center (FLENUMMETOCCEN), in Monterey, California, provides global forecasts and analyses. Environmental data is acquired through links with DOD and NOAA conventional and remotely sensed data distribution systems. By agreement between Navy and Air Force, FLENUMMETOCCEN is the primary DOD global prediction center, running the Navy Operational Global Atmospheric Prediction System (NOGAPS), developed by the Naval Research Laboratory Detachment, also in Monterey.

NOGAPS provides global atmospheric predictions through twice-daily operations runs. However, in near-shore regions, the small-scale interactions between the atmosphere, underlying ocean, and nearby land make it necessary to analyze and predict the battlespace environment at higher resolution. In addition to the global prod-

Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS)

Flexible multi-grid nesting:

- Coarse grid couples to the synoptic scale and refines cloud and moisture features
- 3:1 ratio reduces reflections at boundaries



Complete data assimilation on each nest:

- Shares Quality Control and MVOI software technology with NOGAPS

FNMOC Operational Regions:

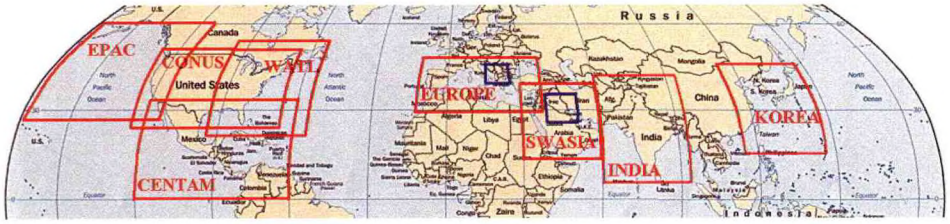


Figure 3-DOD-6. COAMPS is Navy's air-ocean coupled mesoscale model.

uct suite, FLENUMMETOCCEN is uniquely capable of providing high resolution, METOC products on short notice for any location in support of global contingency military and humanitarian operations. Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) is an operational model featuring nested, non-hydrostatic physics, explicit moisture physics, aerosols, and improved data assimilation. Using NOGAPS lateral boundary conditions, COAMPS provides a high-resolution, re-locatable, meteorological and oceanographic prediction capability to support joint littoral operations. COAMPS is routinely run for Europe, Southwest Asia, Korea, Central America, Western Atlantic, and the Eastern Pacific (Figure 3-DOD-6).

NOGAPS and COAMPS forecast products are distributed via various communications systems either directly to Fleet customers or through the Navy regional METOC centers. The regional METOC centers develop value-added products and services tailored to specific operational requirements. Over the next two years, COMNAVMETOCCOM will install computer systems at the regional centers to run COAMPS in-theater, allowing them to respond to Fleet commanders' requirements in near real-time. As a complement to numerical forecast products, FLENUMMETOCCEN provides atmospheric and oceanographic observations, data extracts, and data for tactical decision aids. Additionally, FLENUMMETOCCEN is the designated National Center of Excellence for remotely sensed microwave products under the Air Force/Navy/NOAA Shared Satellite Processing Agreement. The FLENUMMETOCCEN web site is *www.fnmoc.navy.mil*.

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in meteorology is closely linked with oceanography, the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is the National Center of Excellence for satellite-derived sea-surface temperature measurements providing the global sea surface temperature data critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO is a DOD Major Shared Resource Center, enabling creation of the latest research and development models on the most modern scaleable supercomputing architecture and facilitating transition from R&D to operational use. The NAVOCEANO web site is *www.navoceano.navy.mil*.

Tailored Theater and Regional Support

Theater and regional support are provided to forces ashore and afloat through six regional centers delivering METOC services within their broad areas of responsibility (AORs). Aligned with specific Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs), these centers tailor services to theater requirements, and manage and prioritize dissemination of numerical products from FLENUMMETOCCEN and NAVOCEANO. Special products needed to meet requirements of Joint Force Commanders are also generated by the regional centers. Additionally, the Joint Typhoon Warning Center (JTWC) (operated by Navy and Air Force) is co-located with the Naval Pacific Meteorology and Oceanography Center in Pearl Harbor, Hawaii.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy (through NAVICECEN), NOAA, and the United States Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides ice analyses and forecasts for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes to civil as well as military activities.

Local and Aviation Support

NAVMETOCCOM Facilities at Whidbey Island, Washington, Naples, Italy, and at Jacksonville and Pensacola, Florida, provide aviation forecast services as well as Fleet Operating Area (OPAREA) and local forecasts and warnings for aircraft, ships, submarines and naval bases and staffs. Additionally, there are 31 NAVMETOCCOM detachments worldwide. Though primarily situated at Naval Air Stations for aviation safety of flight forecasting, several are located at Naval Stations in support of sea-going units (Figure 3-DOD-7). The detachments provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility. Detachments and facilities within the continental United States use numerical products from both FLENUMMETOCCEN and NOAA's National Centers for Environmental Prediction (NCEP). Overseas detachments and facilities use FLENUMMETOCCEN numerical products, in addition to USAF and foreign products.

Two detachments provide specific technical services. The first is located at the National Climatic Data Center, Asheville, North Carolina, and coordinates the Navy's climatological program as part of the Federal Climate Complex. The second detachment, at Tinker AFB, Oklahoma, manages Naval data requirements for the USAF Automated Weather Network (AWN).

On-Scene Support

The Navy's permanent afloat METOC assets are their OA Divisions, embarked aboard aircraft carriers, major amphibious ships and command ships. The OA division's primary objectives are safety of ships and aircraft, optimum tactical support to embarked warfare commanders, and tailored on-scene products and services for the assigned task force/group and Allied units in joint, combined, or coalition military and humanitarian operations.

Figure 3-DOD-7. Navy's rescue mission requires flexible MTEOC support.

The primary source of on-scene Navy METOC support for other forces afloat and those deployed ashore are deployable Mobile Environmental Teams (METs). These teams provide short-term, on-scene services to DOD activities without organic METOC personnel, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. METOC products and services provided by these teams are tailored to each units' requirements and include tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning.

UNITED STATES MARINE CORPS (USMC).

On-Scene meteorological and oceanographic forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, USMC (Code ASL37) is the cognizant office for Marine Corps meteorological and oceanographic support and requirements. The Marine Corps weather organization consists of two operational chains of command, one for garrison aviation weather units and the other for the Fleet Marine Force (FMF).

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

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

MAJOR METOC SYSTEMS

The capability to provide near real-time global, regional, and local METOC services to the Navy and Marine Corps team requires a robust and evolving set of leading edge technology tools. Theses tools are embodied in the following systems:

Primary Oceanographic Prediction System (POPS). The Primary Oceanographic Prediction System (POPS) produces complex computer-based models of the world's ocean and atmosphere. The system provides METOC forecasts, charts, imagery and operational data sets to support deployed Navy forces worldwide. This data is essential to the safety and effectiveness of the Navy's operational platforms, sensors, and weapons including cruise and ballistic missiles, ships, aircraft, radar and sonar. POPS prediction models must provide horizontal resolutions of 1-5 kilometers and in near real time for use in on-scene tactical decision aids and systems.

POPS is the DOD-approved system that performs global and regional environmental modeling. The POPS, located at Fleet Numerical Meteorology and Oceanography Center (FLENUMMETOCCEN), provides the computing capability required to support DOD's only global atmospheric forecast model under an agreement between the Navy and Air Force. Under an umbrella memorandum of agreement signed in 1993 between NOAA and FLENUMMETOCCEN, both sides will provide cooperative efforts in operational numerical modeling, data exchange, and mutual backup between NCEP and FLENUMMETOCCEN. In 1999, FLENUMMETOCCEN provided numerical modeling backup capability to NCEP for two Atlantic hurricanes and for a five month duration after the NCEP computer-fire outage in October.

POPS is migrating from the Cray C90 architecture to SGI Origin 2000 and Scalable Node architecture three phases during FY 1999-FY 2001. By the end of Phase 3 (FY 2001), POPS will have replacement hardware and software that forms the basis of METOC support throughout DOD. This new capability will include state-of-the-art decoders, data managers, quality control algorithms, and observational assimilating software for all types of METOC data from all available sensors. These data will support state-of-the-art numerical weather, ocean, chemical/biological, and acoustic models, run in multiple nested fashion from global scale models at resolutions of tens of kilometers to battlegroup/battlefield models at resolutions of a few kilometers.

In order to support and sustain military operations around the world, the POPS system performance objective for Phase I is a sustained computational throughput of 100 billion floating point operations per second (100 GFLOPS) on METOC models. This objective will enable operation of state-of-the-art weather and ocean models at resolutions necessary to meet DOD requirements well into the next decade. The POPS system performance improvement objectives will support DOD in the following specific ways:

- Optimal aircraft routing services
- Safe and direct ship routing services
- Hurricane, cyclone, and tropical storm prediction worldwide
- Open ocean and coastal wave prediction
- Precipitation prediction
- Refractivity conditions/ducting range
- Acoustics support
- Ballistic missile targeting support
- Search and rescue
- Low level chemical/biological/nuclear transport prediction

Distributed Atmospheric Modeling Prediction System (DAMPS)

For centuries, military commanders have looked to the weather for tactical advantage. The Navy operates a distributed model in support of tactical weather prediction. DAMPS allows users to ingest high-resolution data and on-scene observations into regional and global model information received from the Fleet Numerical Meteorology and Oceanography Center in Monterey, California. The result is an on-scene weather model that provides accurate weather predictions for an operating area within a 24-hour timeframe.

DAMPS has performed well in initial operations at Naval Meteorology and Oceanography (METOC) centers in Bahrain and San Diego.

During FY 2001, the system will be fielded at other Navy METOC centers worldwide; a later goal is to install the systems on board the oceanography divisions of Navy ships. The system will be integrated with the Naval Integrated Tactical Environmental Subsystem (NITES), a versatile local data fusion center and forecasting system being developed by the METOC Systems Program Office (PMW 185) of Space and Naval Warfare Systems Command in San Diego. Afloat, DAMPS will be able to use real-time weather data from ship and battle group observations, including parameters such as wind, temperature, cloud, visibility, and radar data, and then incorporate this data into its analysis. This analysis can be highly focused on any area of interest. Coupled with NITES, the system will be able to disseminate products and tactical decision making aids back to the military user.

Tactical Environmental Support System (TESS). The Navy is presently undergoing migration towards a modular, interoperable suite of systems to ingest, process, fuse, display, and disseminate METOC data. The program consists of five seamless versions known as the Naval Integrated Tactical Environmental Subsystem (NITES) versions I-V. NITES systems will be fielded in FY 2000 through FY 2004. The five NITES versions are:

- NITES I. Provides Navy decision-makers on major combatant ships with METOC assessments and forecasts, and integrates data with sensor and weapon platform parameters for system performance assessments. Theater METOC Centers use NITES I to provide value-added products to fleet units, and the numerical prediction guidance generated by FLENUMMETOCCEN.
- NITES II. Makes METOC data and products available to Navy and Marine Corps activities afloat and ashore via the Global Command and Control System-Maritime (GCCS-M). TESS data and products are used to feed tactical decision aids resident within GCCS-M. NITES II is the basis for the Joint METOC Segment of the new Global Command and Control System (GCCS) V3.0.

- NITES III. An unclassified forecast, briefing, and display system tailored to Naval METOC shore activities in support of aviation operations.
- NITES IV. A portable system tailored to Mobile Environmental Team METOC requirements. Fielding of NITES IV is expected to commence in FY 2004.
- NITES V. A forecast, briefing, and display system for foreign military sales to ensure interoperability with our allies. It is a follow-on to the Allied Environmental Support System (AESS) and will incorporate capabilities used in the other NITES variants.

Meteorological Data Receiver-Recorder (AN/SMQ-11 and AN/FMQ-17). The principal Navy system to acquire environmental data directly from satellites. There are different equipment configurations for ships (AN/SMQ-11) and shore sites (AN/FMQ-17), and through their interface with TESS variants they provide remotely sensed information to the operator.

Automated Surface Observing System (ASOS). ASOS supports aviation and local area observing requirements at Navy and Marine Corps stations worldwide, leveraging development efforts of the National Weather Service (NWS). ASOS helps assimilate field meteorological parameters and facilitates efficient entry of surface aviation observations and synoptic weather reports into the Automated Weather Network (AWN).

Supplemental Weather Radars. The Navy has procured Supplemental Weather Radars to provide doppler weather radar coverage at selected Navy and USMC sites, mostly overseas, outside of NEXRAD coverage. This system replaced the obsolete AN/FPS-106 weather radars.

Meteorological Mobile Facility Replacement (METMF(R)). The METMF(R) is a transportable system that houses meteorological support equipment for the Marine Air Ground Task Force (MAGTF). This 8 x 8 x 20 foot van provides a fully functioning weather office designed to support Marine Corps expeditionary airfield operations for 30 days without resupply. It includes sub-systems for data collection (local, remote and upper air sensors), data processing, satellite data ingest and display, Doppler radar, communications, briefing support, and support for remote forces. The METMF(R) is interoperable with the Marine Corps C^4I systems and METOC systems of the other Services via the Global Command and Control System (GCCS).

Operational Products and Services

Optimum Track Ship Routing (OTSR), and Optimum Path Aircraft Routing System (OPARS) are advisory services for fleet units. They are based on NOGAPS and COAMPS data, tailored to the customer, and provide guidance to the forecaster for the safe operation and cost-effective routing of DOD ships and aircraft, as they have for nearly 30 years. OTSR and OPARS save the warfighter approximately $57 million/year in reduced fuel consumption.

The Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package developed in 1982 to make FLENUMMETOCCEN numerical products available to front line DOD users. All standard meteorological and oceanographic fields, synoptic observations and basic DMSP satellite imagery is also available. NODDS is available to non-DOD Federal agencies and others in the civilian community through an agreement between Navy and NOAA.

The Joint METOC Viewer (JMV) is a new capability that is integrated into NITES and will eventually replace NODDS. Building on the availability of the Internet and the successful user interface of NODDS, JMV provides an intuitive Graphical User Interface for retrieving, viewing and annotating METOC information. Authorized DOD and Government users with Internet access now have a simple, cost-efficient way to display weather and ocean information on various computer platforms and operating systems. JMV is operational at several hundred DOD sites, including ships.

Since 1983, the Naval Regional Meteorology and Oceanography Center, in Norfolk, Virginia, has provided long range forecasts in support of Energy Conservation efforts at Naval shore installations in the continental United States. The services are primarily in the form of extended-range (10 day) temperature forecasts provided to energy managers to assist in optimizing power plant operations. Monthly temperature/degree day outlooks and long-lead (12 month) seasonal and precipitation forecasts are also issued to assist in strategic planning of fuel purchasing and resource allocation. Documented savings from the Energy Conservation Forecast Program exceed $62 million, with the majority of savings resulting from power plant steam/air conditioning on/off recommendations and energy resource/fuel allocation based on long-lead forecast products. Customers include 128 Navy and Marine Corps facilities and commands.

SUPPORTING RESEARCH

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

The Navy is a world leader in the field of numerical weather prediction for marine environmental services.

Transitioning fundamental scientific research, through additional development, into operational meteorological and oceanographic models is key to a successful numerical prediction program. This ongoing process includes work at universities and the Naval Research Laboratory's Marine Meteorological Division to keep the Navy Operational Global Atmospheric Prediction System (NOGAPS) and the Coupled Oceanographic and Atmospheric Mesoscale Prediction System (COAMPS) at the leading edge of technology. Development is also underway to improve data assimilation, quality control, and management techniques to support these models. A major numerical weather prediction thrust is underway to develop a shipboard tactical atmospheric forecast capability to assimilate locally acquired data in real time and deliver high resolution (5 km), limited area (100s of km), short range (12-24 hour) atmospheric predictions in tactical timeframes.

The Navy R&D program in remote sensing develops techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are exploited to the greatest extent possible and plans are in place to incorporate new capabilities when introduced. Because many satellite processing algorithms are designed for use with tactical systems, expert or rule-based processes are used where possible to reduce human-intensive interpretation.

ONR and SPAWARSYSCOM continue to explore techniques for assimilating environmental data through non-traditional sensors. One such effort is investigating the AEGIS Weapon System's AN/SPY-1 radar and developing the ability to produce NEXRAD-like radar information from ships at sea.

Interagency Cooperation

Navy and Air Force have long been cooperating in DOD weather support, and these efforts have led to such successes as the Defense Meteorological Satellite Program and the Joint Typhoon Warning Center. Recently, the two services have reinvigorated efforts to increase efficiencies in their METOC programs through greater cooperation. The NAVAF-21 Charter, signed in June 1999 by the Oceanographer of the Navy and the Air Force Director of Weather, expands on the 1992 NAVAF Agreement for long-term cooperation in DOD operational METOC efforts. NAVAF-21 implements mechanisms to formalize information exchange and cooperation, focus limited resources and prioritize issues to most efficiently meet long-term DOD METOC requirements, and establish an enduring methodology for documenting and periodically reviewing decisions on areas of mutual interest.

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

- Cooperative efforts in operational numerical modeling, data exchange, and mutual backup between FLENUMMETOCCEN and the National Centers for Environmental Prediction (NCEP).
- Navy/NOAA/Coast Guard operation of the National Ice Center.
- Air Force Weather Agency (AFWA)/Navy/NOAA agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement and installation.
- Satellite altimetry data processing.

MOAs also exist between the Department of Commerce, Department of Transportation, and the Department of Defense concerning procurement and operation of NEXRAD. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).

Natural Disaster Mitigation

Navy METOC plays a vital role in reducing the impact of natural disasters to units both ashore and afloat. Severe weather warnings are issued at Naval facilities by the local NAVMETOCCOM activity when conditions warrant. For ships operating at sea without METOC personnel embarked, tailored en route weather forecast messages (WEAX) and high winds and seas warnings provide commanding officers with advance notice of heavy weather, and Optimum Track Ship Routing (OTSR) forecasters monitor ship movements and provide heavy weather avoidance recommendations.

Tropical cyclones and even severe winter storms provide even greater challenges, as ships cannot generally "ride out" storms in-port without sustaining damage (Figure 3-DOD-8). Similarly, once they get underway (or "sortie") ships must steer well clear of the highest winds and seas, to avoid personnel injuries and damage and ensure their stability limits are not exceeded. Even storms of little consequence to the general public--those that remain well out at sea--are still of

Figure 3-DOD-8. USS John F. Kennedy (CV-67) encounters heavy seas as it heads into Hurricane Floyd on a rescue mission.

great concern to the Navy. Because of the need to sortie ahead of tropical cyclones, the Navy must make decisions 3 to 5 days in advance of potentially dangerous weather. Sortie decisions are extraordinarily difficult to make because of their high cost and impact on personnel and operations. In making these decisions, Fleet commanders must strike a balance between the risk of staying in port versus the cost and potential for damage at sea.

Forecasts are provided to the fleet commanders and their staffs by the nearest NAVMETOCCOM activity. Within CONUS, the forecasts are closely coordinated with the National Weather Service. Overseas, local warnings and forecasts are based on guidance provided by the Joint Typhoon Warning Center, Pearl Harbor, Hawaii.

ARMY OPERATIONAL SUPPORT

OVERVIEW OF OPERATIONAL EQUIPMENT AND SUPPORT MISSIONS

United States Army weather support is a mix of Army and United States Air Force (USAF) personnel and equipment under Law and according to Army-Air Force (AF) agreement. Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, Weather Support for the United States Army, 30 June 1996 describes the Service responsibilities and those of Major Army Commands (MACOMs) within the Army providing weather support. The United States Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers (Figure 3-DOD-9). AF Major Commands (MAJCOMs) provide operational weather services to warfighting MACOMs in combat, contingencies, and peacetime training. United States Army Forces Command (FORSCOM), United States Army Europe (USAREUR), United States Army Pacific (USARPAC), United States Army Special Operations Command (USASOC), Eighth United States Army (EUSA), and United States Army Training and Doctrine Command (TRADOC) have AF Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) crews provide direct upper air observation support to artillery units in the same MACOMs. During peacetime training and activation the Air National Guard (ANG) provides AF operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies the ANG may augment the active Army Combat Weather Teams (CWTs). The ANG acts like an AF MAJCOM in providing support to the Army RC.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and United States Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is described under Army Test and Evaluation Command. SMDC provides weather support to Kwajalein Missile Range (KMR)

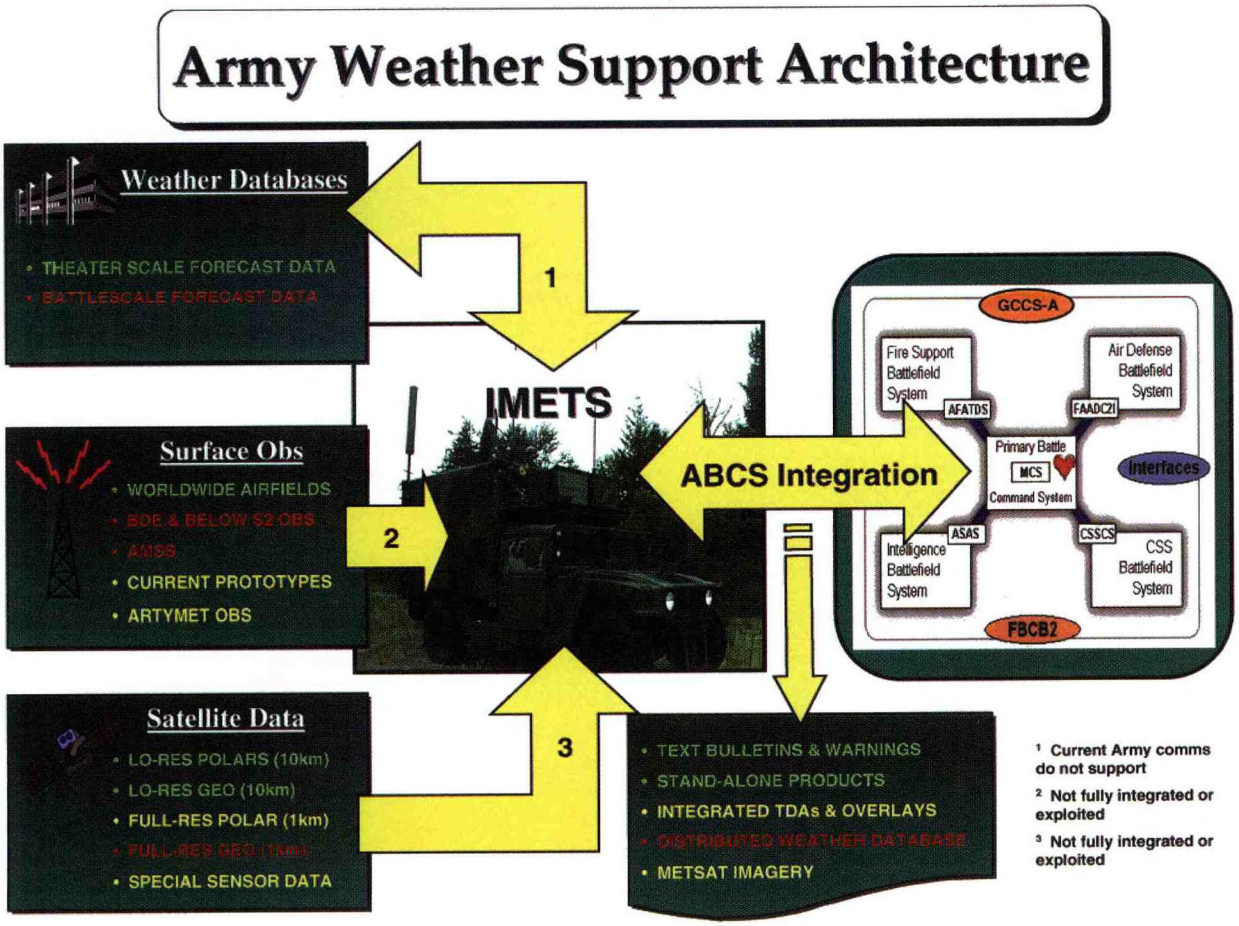


Figure 3-DOD-9. Army Weather Support Architecture.

through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF CWTs for tactical operations. The Integrated Meteorological System (IMETS) is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence Fusion. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to PD, IMETS and to Field Artillery meteorology programs. Previously issued Block I IMETS have been upgraded to ensure Y2K compliance. Block II IMETS currently being issued are Y2K compliant. IMETS fielding continues in FY 2001.

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

ARTYMET crews in the Active Component (AC) and some RC sections currently use the Meteorological Measuring Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations. It is a mobile, upper air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire, to USAF CWTs, and to the Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations. The CECOM section provides a complete description of MMS. The Meteorological Data System (MDS), AN/TMQ-31, replaced by the MMS, has been reissued to the Army National Guard (ARNG) and will be used as long as still supportable. The rest of the ARNG units will be upgraded to the MMS and future Profiler systems, as they become available. The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirement documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

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

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

Army Operational Support provided by the Air Force

Under AR 115-10/AFJI 15-157, the AF is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison weather support requirements. Army support manpower requirements are sourced from AF active, reserve, and ANG weather units. While direct support of the Field Artillery remains an Army responsibility and is supported by Army ARTYMET teams, AF CWTs provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the warfighting MACOMs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and special forces groups/ranger regiments to provide direct, on site weather support. AF weather squadrons and flights provide garrison and tactical weather warning, observing, forecasting, special support, and staff weather officer (SWO) services to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection. The AF is responsible for installation, operation, and maintenance of standard AF meteorological and observing equipment at Army Airfield Weather Stations (Figure DOD-10). Tactically, the Army is responsible for vehicles,

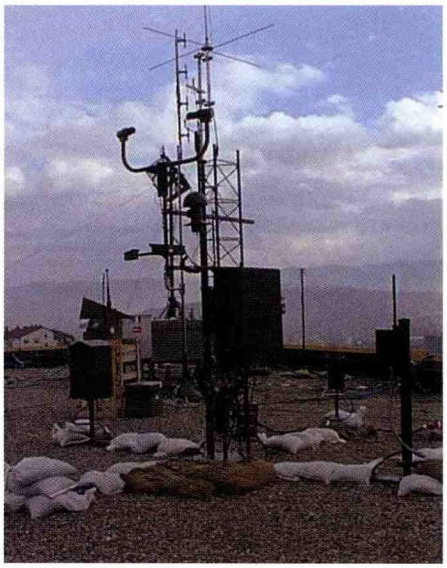


Figure 3-DOD-10. Automated observing equipment deployed to Kosovo.

tactical communications, and weather effects criteria. The Army IMETS is fielded for these purposes and is operated by AF CWTs. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is built on an Army vehicle, uses Army tactical communications and Army weather effects software. The Army provides other tactical equipment to AF CWTs through an Army Table of Organizations and Equipment (TOE).

United States Army Space and Missile Defense Command (USASMDC)

The Space and Missile Defense Battle Laboratory (SMDBL), a component of USASMDC, conducts experimentation, testing, and integration activities for the purpose of providing space based weather products to Army and joint command and control system users. In 1999, SMDBL deployed one Deployable Weather Satellite Workstation (DWSW) and one operator/trainer in support of the V Corps Staff Weather Officer at Task Force Hawk, Tirane, Albania. The DWSW provided direct downlink of the Meteosat 7 imagery every 30-minutes into the SWO shelter. Imagery was then applied to the Army aviation mission as well as force and asset protection.

The High Energy Laser Systems Test Facility (HELSTF), a subcommand of USASMDC located on White Sands Missile Range, is designated as the DOD National Test Range for high energy laser test and evaluation. In addition to laser systems test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HELSTF activities by providing atmospheric propagation and meteorological measurements, planning, and analysis as required. These capabilities also support the safe storage, handling, and use of the toxic laser fuels.

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

Army Corps of Engineers Civil Operational Activities

The Corps of Engineers (COE) uses a network of about 8,810 land-based gauges. About 55 percent of the sites collect meteorological data, 35 percent a combination of hydrologic and meteorological data, and 10 percent hydrologic or water quality data. The Corps funds or partially funds 61 percent (4,500) of all the gauges it used. Meteorological gauges commonly measure precipitation and temperature. All data is used in the regulation of COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/National Weather Service (NWS) to collect and maintain precipitation information from 600 of meteorological sites. Similarly, COE transfers funds to the United States Geological Survey to maintain precipitation data collection from 500 sites, while the COE maintains the rest. Eight-two percent of all Corps sites provide real-time data via satellite microwave meterbursts, landlines, or radio. Data from all COE networks are available and used by other federal, state and local agencies.

Eighth United States Army Support

Eighth United States Army (EUSA) requires, and uses, Army resources to conduct two major meteorological services in direct support of Army operations: collecting and disseminating upper air observations for artillery support, and collecting and disseminating limited surface weather observations to support all tactical units and operations.

Two artillery meteorological (ARTYMET) crews with the Second Infantry Division use AN/TMQ-41 Meteorological Measuring Sets to collect upper air observations for direct use by field artillery units. ARTYMET crews also collect routine (usually daily) upper air observations for training; these observations are typically fed into the global weather database.

Additionally, under the Forward Area Limited Observing Program (FALOP), Army personnel use tactical weather kits to collect limited weather observations in data sparse, forward areas. Observations are typically collected by intelligence personnel at brigade and battalion tactical operations centers (TOC) during contingencies or exercises and, in turn, are disseminated to and through AF weather teams supporting Army air, ground, or special operations. These observations will be used by forecasters at the 607th Weather Squadron (607 WS) Theater Forecast Unit (TFU) to accurately predict mission limiting weather in the DMZ.

The USAF is planning on the purchase of automated COTS observing systems for eight locations in the area of the DMZ. Observations from these systems will be transmitted via phone lines to pilots, as well as to forecasters back in the 607WS TFU. They will also be incorporated into the global weather database to improve short term forecasting in the northern ROK.

Army Operational Support Provided by USAF

USAF weather personnel assigned to the 607th Weather Squadron (607 WS) provide fixed and tactical weather support to EUSA units and installations. 607 WS provides garrison and tactical weather warning, observing, forecast, special support, and staff weather officer (SWO) services during contingency, exercise, or armistice operations. 607 WS units provide direct, on-site support at eight EUSA installations and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions. In FY 2000, the 607 WS reengineered weather support in theater and the 607 WS TFU took over forecasting responsibilities for the eight EUSA locations. The EUSA Cadre Weather Teams will now be primarily responsible for providing their customers with observations and tailored support (Figure 3-DOD-11). 607 WS provides 97 trained weather personnel and required fixed and tactical weather sensing, data processing, and communications equipment. EUSA provides supporting USAF units needed tactical vehicles, MTOE, and CTA equipment, and operating funds (for expendables, maintenance, etc.).

Figure 3-DOD-11. Army CH-47 Transport helicopter.

Training and Doctrine Command (TRADOC) Programs

HQ TRADOC is responsible for development and management of training programs, writing Army and Joint weather support doctrine (concepts and field manuals), and establishing the weather requirements documents for Army tactical weather support equipment. Headquarters, TRADOC is the approval authority for Army-AF weather doctrine, Army weather hardware requirements, and weather support policy.

Key mission area for the next few years will be to coordinate Army weather support requirements during Air Force Weather Reengineering and Army Task Force XXI Advance Army Warfighting Experiments (AWEs). Deployed weather support will improve significantly with the digitization of these experimental Army units. Customized battlefield weather "visualizations" transmitted via the IMETS will take the place of the stand-up weather briefings of the past. The results of the AWEs will show new tactics, techniques, and procedures for the exploitation of weather during military operations. Identified software enhancements will transition to the appropriate materiel developer for further integration. Finally, these experiments provide an opportunity to educate Army leaders and their staffs on the effects of weather on the battlefields of the future.

The Schools and Battle Laboratories

The United States Army Intelligence Center and Fort Huachuca (USAIC&FH) is the functional proponent for Army tactical weather support. USAIC&FH represents the warfighter by developing solutions to satisfy Army weather requirements. In addition, it serves as the proponent for the *"Owning the Weather"* (OTW) program - a concept for exploiting weather as a force multiplier on the battlefield. The key component to OTW is IMETS, which is being fielded by the Army and operated by Air Force Combat Weather Teams.

The USAIC&FH Weather Support Team (WST) advises the USAIC&FH, ARL, and Air Force Weather (AFW) on Army weather support issues and helps develop solutions to meet both active and reserve forces' requirements. In addition, the WST monitors weather support training to Intelligence and AFW personnel supporting the Army (e.g., the Staff Weather Officer Army Indoctrination Course), and establishes requirements documents for weather support equipment.

Over the last year, the WST updated and expanded a large portion of the weather effects critical threshold value database to be incorporated into the Integrated Weather Effects Decision Aid (IWEDA). They also played a key role in the following initiatives: development of a weather module for the Federation of Intelligence, Reconnaissance, Surveillance, and Targeting Operations and Research Models (FIRESTORM); Joint IWEDA program; and Joint Target Acquisition Weather Software (TAWS). The WST participated in the ongoing Army Force XXI and AFW Reengineering process and programs. Finally, they developed and wrote a new Operational Requirements Document (ORD) for IMETS, and developed concepts for weather support into the Tactical Unmanned Aerial Vehicle (TUAV), and Brigade Combat Team.

The Staff Weather Officer at the United States Army Combined Arms Center facilitates modifications to the TOE for Army CWTs, and through the TRADOC System Manager for Army Battle Command System and Battle Command Battle Lab-Leavenworth, provides environmental data for the Command, Control, Communications, Computer and Information (C^4I) network. In addition he works in the White Cells during Army Warfighter Experiments to ensure weather is representative and accounted for in the modeled AO.

The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, is the proponent for upper air meteorological support to the

Army. Artillery meteorological crews, Active and Reserve, currently use the AN/TMQ-50 to measure surface weather parameters, and the AN/TMQ-41 Meteorological Measuring Set (MMS) to take upper air observations. The MMS provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to USAF CWTs for weather forecasting; and to the Chemical Officer for obscurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations. We will be working with USAFAS to ensure that these surface and upper air observations are shipped back to weather centrals where they can be ingested in to our newest mesoscale models.

The Engineer School (USAES), Fort Leonard Wood, Missouri, coordinates weather support requirements for Terrain Analysis and Topographic Engineering. USAES develops methods of measuring and forecasting state of the ground for trafficability assessments using input weather data fields. Their mission also includes identifying and documenting requirements to interface meteorological and engineer battlefield systems. Due to force cuts, USAES no longer has a full time civilian meteorologist in the Terrain Visualization Center, DCD. (Operating Location B, 3rd Weather Squadron, USAF, provides weather observation services at Forney Army Airfield, Fort Leonard Wood, Missouri. OL-B is included in this report only to the extent that Fort Leonard Wood provides funding for its expendables and overhead.)

The Army Military Police and Chemical Schools now reside at Ft Leonard Wood. Neither currently employ staff meteorologists.

The Aviation Center at Ft Rucker incorporates weather instruction and procedures into rotor-wing training programs in their mission areas. The Center has requirements for weather observations and USAF forecast support at Cairns Army Airfield, Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay weather intelligence and resource protection advisories to numerous Army remote training sites.

The weather units at Ft Benning, Ft Knox, and Ft Huachuca provide airfield observing and forecast support to their respective Army posts.

United States Army Special Operations Command (USASOC)

Weather support to USASOC provides for planning, command decision, and mission execution weather forecasts and observations to improve efficiency, effectiveness, and safety of operations for USASOC units. USASOC personnel provide limited meteorological observation services in direct support of Army operations using tactical weather kits to collect limited weather observations in data sparse, permissive and non-permissive environments. Observations are typically collected by Army Special Operations Forces at the team level and are passed to operating bases for use by Army commanders and staff, as well as USAF SOWT personnel. USAF weather personnel supporting USASOC are assigned to the 10 CWS. The 10 CWS provides garrison and tactical weather support to USASOC units including the 75th Ranger Regiment and three subordinate Battalions, the 160th Special Operations Aviation Regiment and three subordinate battalions, and five Special Forces Groups and their subordinate battalions. Weather support encompasses climatological information, mission forecasts, command decision forecasts, aviation forecasts and observations, drop zone forecasts and observations, special reconnaissance, and Foreign Internal Defense/Unconventional Warfare. The 10 CWS also provides staff support to USASOC, the United States Special Forces Command, and the United States Army John F. Kennedy Special Warfare Center and School. USASOC provides supporting USAF units with required tactical vehicles, communications equipment, tactical equipment, and operating funds (for expendables, maintenance, etc.).

USAREUR/7th Army

United States Army Europe (USAREUR) and 7th Army require and use Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations.

7th Weather Squadron provides USAREUR/7th Army in-garrison and tactical weather intelligence and support. This includes observing services for in-garrison, contingency and exercise operations, staff weather officer (SWO) services as well as special support. The Operational Weather Squadron (OWS) at Sembach AB provides operational-level forecast products for the EUCOM AOR, to include all USAREUR units. Combat weather flights evaluate and tailor these forecast products to produce mission execution forecasts.

The Automated Meteorological Information System (AMIS) is the primary in-garrison weather equipment for receiving graphics and alphanumeric data. Data is received via VSAT and hard-wire circuits. The New Tactical Forecast System (NTFS) is the primary equipment used for deployed locations with data received via NIPRNET and SIPRNET. Units also use the NATO Automated Meteorological Information System (NAMIS) to receive NATO generated weather products. NAMIS software is hosted on a laptop and receives data via VSAT. Satellite imagery (METEOSAT and DMSP) is received via the Small

Tactical Terminal (STT). Five IMETS have been fielded within USAREUR. Two Portable Automated Observing Systems (PASOS) and a Tactical Weather Radar (TWR) are deployed to Task Force Falcon (TFF), Kosovo, with two additional PASOSs scheduled to be deployed in the near future.

USAREUR provides supporting USAF units with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four ARTYMET sections collect upper air observations for direct use by field artillery units. The FALOP consists of Army personnel taking limited observations at forward areas in the battlespace.

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

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

Corps of Engineers

The Corps of Engineers (COE) Engineer Research and Development Center (ERDC) performs military engineering and civil works research through its seven laboratories at 4 geographic sites (Champaign, Illinois, Fort Belvoir, Virginia, Hanover, New Hampshire, and Vicksburg, Mississippi). The ERDC manages the Military Engineering research program addressing a wide range of topographic and combat engineering future operational capabilities (FOCs). The ERDC also is responsible for reviewing all emerging Army systems for environmental effects, as stated in AR 70-1. Many of the tactical decision aids (TDAs) developed within the military engineering program interpret the impact of weather and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical values define system limitations and are used by decision-makers to take advantage over opposing forces. Technology advancements are transitioned to terrain and weather systems such as the IMETS, the Digital Topographic Support System (DTSS), the Army Tactical Command and Control System (ATCCS). The COE Topographic Engineering Center (TEC), Fort Belvoir, Virginia, provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This support includes the development of: (1) environmental effects databases and models that are relevant to military plans, operations and the acquisition communities; (2) models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds; and (3) integrated software modules that are designed to be exploited in the synthetic environment arena and techniques to portray natural and induced battlefield environments, thus enhancing computerized battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. The Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, conducts research in sensor signal interaction

Figure 3-DOD-12. CRREL research supports Army's worldwide need for trafficability studies and data.

with snow, ice, and frozen soil, icing accretion on surfaces and structures, deicing technologies, and cold regions surface-air boundary process. CRREL develops databases and models predicting infrared and millimeter wave weapon system performance, and the capability of technology to enhance military operations in cold environments. Other specific programs include weather effects on environmental research for military training lands, helicopter pre-flight deicing and airborne icing avoidance, remote sensing for predicting snow coverage and snow-water equivalence for snow melt runoff, and modeling winter effects for input into Army operational and training models and simulations (Figure 3-DOD-12).

Army Materiel Command

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

The ARL Battlefield Environment (BE) Division is the lead DOD agency for research and development in the

portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer. BE's mission is to provide the technology and tools (1) for the Warfighter to exploit weather on the battlefield, (2) for the Commander to avoid exposing the Soldier to environmental hazards, and (3) for the Materiel Developer to minimize system weather impacts, supplying atmospheric effects information. The joint Army/AF OTW initiative will provide knowledge of current and forecast battlefield environment conditions, along with their effects on systems, soldiers, operations, and tactics, to contribute to the Army's decisive advantage over its opponents. Within the DOD, BE is the lead agency for multi-service R&D programs in transport and dispersion modeling, boundary layer meteorology over land, and mobile atmospheric profiling. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, boundary layer processes, and atmospheric effects. The BE program is driven by the Army's need for meteorological information at smaller scales than used by either the AF, Navy, or civilian community, and over data-sparse geographic regions. While the AF provides the Army with is basic tactical weather support, the Army provides technology to support such service-unique requirements, and Army systems, as well as distributing this weather intelligence information to the Army Battle Command Systems (ABCS) on the battlefield.

The Army has begun an active re-programming to respond to the new AF Weather Re-Engineering initiatives, and will work to ensure the ongoing success of the Army weather intelligence technology. BE continues to develop and provide the software tools for the Army's IMETS and works with the AF Weather Agency and Combat Weather Center to make IMETS an integral part of the total battlefield weather support mission.

The BE Division within the ARL Information Science and Technology Directorate, consists of four Branches, two each at the ARL primary site at Adelphi, Maryland, and the White Sand Missile Range, New Mexico. The Adelphi, Maryland, Branches specialize in a basic research program, while the WSMR Branches support an applied research development program for Army tactical applications. BE opened an experimental site at Blossom Point, Maryland, in mid-1998, in a complex littoral region on the north shore of the Potomac River, and will conduct field experiments in electro-optic and acoustic propagation, as well as test weather modeling tools.

At the Adelphi Laboratory Center (ALC) in Maryland the two branches are (1) the Atmospheric Acoustics and Electro-Optics (A&EO) Propagation Branch and the (2) the Boundary Layer Meteorology and Aerosol Research Branch (BLM&AR). The A&EO Branch provides basic research in the modeling and simulation of environmental effects on acoustic and electro-optics propagation, and laboratory and field experimental research into environmental effects on acoustic and electro-optic propagation and the mitigation of those effects. The BLM&AR Branch conducts a research program in the micrometeorological processes and structure of the atmospheric boundary layer. This program focuses on the interaction of the land-air interface with wind fields, turbulence, and fluxes and on optical methods of detection of aerosols (primarily chemical-biological agents) and the modeling of their transport and dispersion in the tactical environment.

The Weather Exploitation Branch, Battlefield Environment Division's R&D efforts involve several areas. They address tactical weather data assimilation and distribution, to include exploitation of commercial and military satellite technology to move meteorological data to the battlefield Tactical Operations Centers and between echelons. They generate gridded meteorological databases to support C^4I systems, mission planning and rehearsal, and integrate weather forecast analysis tools to identify the location and timing of hazardous and significant weather at small scales in the boundary layer. They develop rule-based tactical decision aids for impacts of weather on military systems, platforms, and operations. And, they integrate physics based weather effects models and meteorological satellite analysis algorithms with weather data visualization tools for improved mission planning and situation awareness. As part of the tactical weather product development, the branch also performs the following: configuration management and validation of new products; improvements through end-user feedback from Advanced Warfighting Experiments, TRADOC Concept Experimentation Programs, and integration at the Army's Central Technical Support Facility at Ft. Hood; and delivery of software for integration into IMETS. The IMETS integration includes tactical weather overlays, databases of dynamic gridded weather parameters, weather effects decision aids, and weather data visualization tools, all of which can be executed in the field using Common Hardware/Software and Common Operating Environments.

BE develops the weather application software for IMETS that is part of the Army's effort to Digitize the Battlefield and will provide weather capabilities in the Army's First Digitized Division (FDD) in FY 2000 and the First Digitized Corps in FY 2001. From FY 1997 to the present, BE has successfully used the Army's Task Force XXI AWE's to evaluate and improve its delivered IMETS Block I and Block II software. In FY 1999 and FY 2000 the BE/IMETS tactical weather applications were being upgraded and deliv-

ered for integration to the other C⁴I tactical systems operating under the Army Battle Command System, version 5.0 (ABCS 5.0) (Figure 3-DOD-13). These IMETS applications incorporate significant changes in the sharing of data between Battlefield Functional Areas by exploiting client/server relationships and the IMETS Gridded Meteorological Database. The weather overlays are converted to use the Joint Mapping Tool Kit (JMTK) software for map overlays. And the initial integration of AF Weather Re-engineering includes passing meteorological data and products from AF central hub sites to the Army battlefield TOC's using WMO data standards such as GRIB and BUFR. The weather impact rules and critical values for the BE-developed IWEDA are being assembled jointly across the services to provide a common rule-base for weather impact decision aids.

Figure 3-DOD-13. Army's *"Owning the Weather"* initiative will enable combat units to use weather as a force multiplier.

The Army Research Office (ARO), Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamics and kinematics processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investigator program and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Other areas of special funding are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (EPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. At the Army Research Office, funding for basic research remains relatively static. Increased funding will come if special program initiatives or requests are approved. The primary focus will be on analysis and understanding of data taken in a recent field study of the stable boundary layer.

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

Meteorological Measuring Set (MMS), AN/TMQ-41.

The National Guard is being modernized through the purchase 40 MMS's beginning in FY 1999 and continuing through FY 2002. This will be the final Army buy of the MMS. The Intelligence and Information Warfare Directorate (I²WD) is providing technical support to the system manager (CECOM Logistics and Readiness Center) for this effort. All Active Army units have been fielded. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system is a non-developmental item (NDI). The contractor, Environmental Technologies Group (ETG), has previously built 42 systems for the Army and National Guard, 21 systems for the Marines, and 11 systems for Foreign Military Sales (10 for Canada, 1 for Bahrain). An FY 1999 contract bought 16 systems for NG units and 7 for Egypt. These systems were delivered in FY 2000 and fielded in FY 2000 and FY 2001. Additional NG systems are planned for FY 2001 and FY 2002.

Meteorological Measuring Set-Profiler (MMS-P) System

The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. It will provide new capabilities to determine target area MET. The MMS-P will provide the Field Artillery with modernized and enhanced data collection and automated analysis of current weather conditions along the trajectory and in the target area. The system will

consist of a suite of sensors and associated software models, which provide information along the trajectory or at a point where the munition is expected to engage a target. Weather information will be generated by a mesoscale atmospheric software model that will provide updates every 30 minutes. Modeling will be transparent to the operator. Profiler will be a replacement to the MMS. It will interface with Fire Support systems and IMETS. CECOM is providing technical assistance to PM, NV/RSTA on the program. The current plan is to procure four Engineering and Manufacturing Development (EMD) models in FY 2000, with testing and a production decision scheduled for FY 2002.

Integrated Meteorological System AN/TMQ-40B

The IMETS is the weather component of the Intelligence Electronic Warfare (IEW) sub-element of the Army Battle Command System (ABCS). The IMETS provides commanders at all echelons with an automated tactical weather system that receives, processes, and disseminates weather observations, forecasts, battlefield visualization, and weather effects decision aids to all Army Tactical Command and Control System (ATCCS) Battlefield Functional Areas (BFAs). IMETS receives weather information from polar-orbiting civilian and defense meteorological satellites, civilian forecast centers, the Air Force Weather Agency, artillery meteorological sections and remote sensors. IMETS processes and collates forecasts, observations, and climatological data to produce timely and accurate weather products tailored to the specific warfighter's needs. The most significant weather and environmental support to warfighters are the automated tactical decision aids. These graphics display the impact of the weather on current or planned operations for both friendly and enemy forces. The warfighter can thus more effectively employ his forces and weapons systems to achieve success in battle.

FY 2000 and FY 2001 efforts will focus on completing fielding of the AN/TMQ-40B version systems. FY 2000 efforts will also include developing support documentation to achieve a Milestone III decision for the IMETS Light Configuration system currently scheduled for 4th Quarter of FY 2001. The Light Configuration system is one of the three different configurations called for by the Operational Requirements Document (ORD). The ORD is expected to be approved in 3rd Quarter of FY 2000.

Army Test and Evaluation Command

Developmental Test Command (DTC), (formerly under Army Materiel Command), providing operational support to 9 ranges and test sites with MET Teams. Under responsibilities established in Army Regulation 115-10/AF Joint Instruction 15-157, the DTC MET Teams provide weather support and atmospheric characterization to Army RDTE. MET Teams provide atmospheric data collection, analysis, consultation, warning, and forecast services for Army and other DOD RDTE. MET Team FY 1999 funding has been level for 4 years following several years of decline, using a combination of both programmed funds and users funding. This enables DTC to continue basic meteorological support at Army RDTE ranges and sites, but meteorological instrumentation will be acquired through Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements. DTC MET Atmospheric Sciences Team has a 5-year effort with the National Center for Atmospheric Research (NCAR) to greatly improve "range scale" (mesoscale to microscale), forecasting and analysis technology. Using the MM5 model as a base, this Four Dimensional Weather (4DWX) System (Figure 3-DOD-14) will present both real-time and forecast three dimensional pictures of the MET and other atmospheric characterization parameters in, around, and up to 50K ft over the Army's test ranges. The 4DWX system will provide improved test

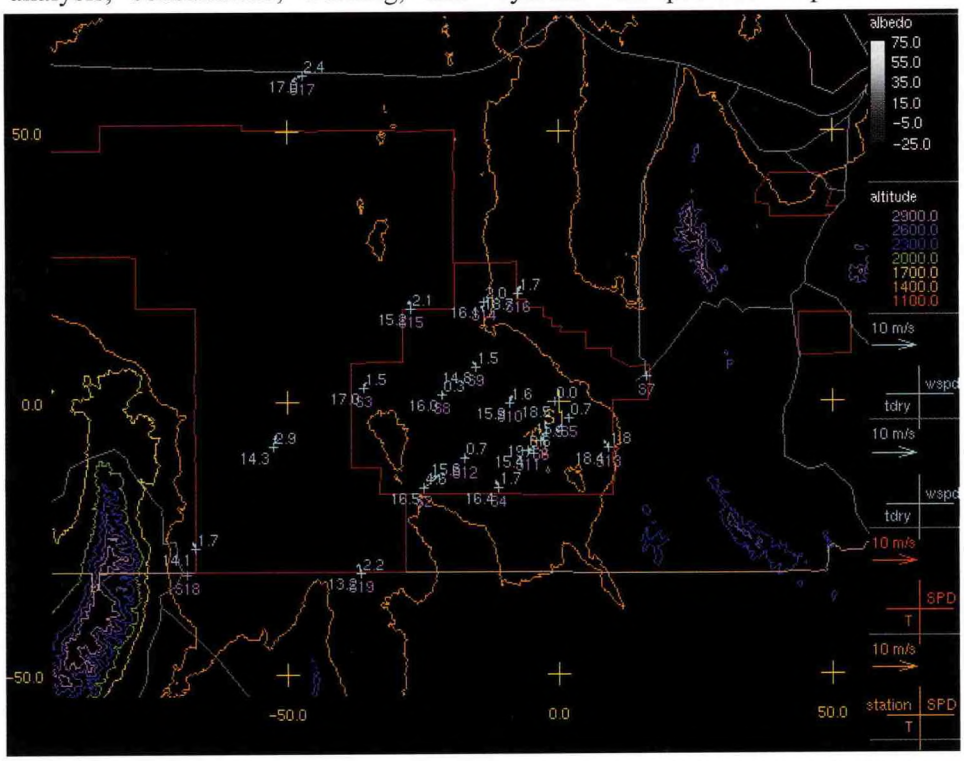


Figure 3-DOD-14. Topographic altitude contour and GOES-Vis Albedo plot from Army's 4 Dimensional Weather System--4DWX.

scheduling, more accurate placement of sensors during a test, more cost-effective measurements, data sets and algorithms for virtual testing, and instantaneous forensic analysis (instant replay) of the conditions that occurred during the test.

In addition to RDTE support, the Dugway Meteorology and Obscurants Division's Modeling and Assessment Branch provides the following specialized services: (1) atmospheric model verification and validation, to include algorithm evaluation and the generation of validation data sets, (2) chemical/biological threat analysis, detection, and decontamination tests and studies through the Joint Contact Point (Project DO49), and (3) prototype development of virtual proving ground meteorological support. Division members also serve on various national and international committees addressing issues related to meteorological measurements and atmospheric dispersion modeling.

Medical Research and Materiel Command

The United States Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude, and nutritional status on the health and performance of individual soldiers and combat crews operating Army systems.

Applied research in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM's weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios.

Weather related research efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dismounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days.

The environmental heat stress monitor (HSM), a pocket-sized electronic device, combines the USARIEM heat strain prediction model with a miniaturized sensor suite to measure air temperature, humidity, wind speed, solar radiation, and barometric pressure. This device provides tailored local guidance on optimal work/rest cycle limits, safe work time, and hourly drinking water needs for a wide range of clothing types and work categories.

The Operational Medicine Environmental Grid Applications (OMEGA- Formerly MERCURY) test bed is an automated heat and cold injury risk assessment system for battle-scale regions (up to 200 X 200 kilometers). It combines digital terrain data and real-time weather information with physiologically-based thermal strain prediction models and displays prevailing risk as color-coded map overlays. This research tool has been operating continuously since June 1996 at USARIEM and the Army Ranger training facilities at Eglin Air Force Base in Florida. OMEGA provides a robust, extensible platform for evaluating thermal strain prediction model performance prior to their transition to operational systems such as IMETS.

As part of the Warfighter Physiological Status Monitoring (WPSM) program at USARIEM, technologies to support access and fusion of real-time local environmental sensor data with individual warfighter physiological sensor data are being investigated. The effective fusion of these two real-time data streams would enable physiological and performance status prediction capability for individual warfighters. A Small Business Innovative Research (SBIR) project to design and build a very small wireless network-capable, expendable, micro-environmental sensing system has been initiated and the feasibility of on-body environmental sensors is also being investigated.

DEPARTMENT OF TRANSPORTATION WEATHER PROGRAMS

The Federal Aviation Administration (FAA) has the responsibility to provide national and international leadership in the optimization of aviation weather systems and services. This leadership is manifested through the management of a safe and efficient National Airspace System (NAS) and the encouragement of consensus and cooperation between government agencies, private weather services, research organizations, and user groups involved in aviation weather. The Federal Highway Administration (FHWA) manages programs that provide federal financial and technical assistance to the states, promotes safe commercial motor vehicle operations, and provides access to and within national forests and parks, native American reservations, and other public lands. Safety, efficiency, and mobility in these programs requires the incorporation and use of timely weather and road condition information. The United States Coast Guard (USCG) meteorological activities include the taking, collection, and transmission of marine and coastal weather warnings and observations; deployment and maintenance of offshore environmental monitoring buoys; and the operation of long-range radionavigation networks.

FEDERAL AVIATION ADMINISTRATION

AVIATION WEATHER MANAGEMENT

The Federal Aviation Administration (FAA) has the leadership role for the national aviation weather Program. The FAA focus for Aviation Weather has been to promote safety first, then improve the National Airspace System (NAS) efficiency to promote reductions in the delays and re-routing due to weather. The Administrator has launched *The Safer Skies, A Focused Safety Agenda*, which includes special analysis teams to document the series of events leading to documented accidents, and other teams to develop intervention actions to eliminate or reduce the causes in the decision making process. Weather has been made a standard consideration in all aspects of the operation and architecture of the NAS.

Aviation weather needs from the field, federal agencies, and industry are entered into the Acquisition Management System (AMS) through which all new programs and changes to the NAS are processed, evaluated, validated, engineered to a requirement, and acquired. The Aviation Weather Directorate (ARW) in the Air Traffic System Requirements Service (ARS) has the responsibility to guide all initiatives through the AMS process and organization, including the Integrated Requirements Team, the Integrated Product Team and the Decision Boards; to assure the development continues to meet the original need; and to guide the activity should the need be evolving. ARW has added improvements to the AMS process whereby non-system (i.e. service improvement or rule changes) solutions will receive the same rigorous evaluation and validation.

FAA has been focusing on four major areas for aviation weather services. This focus has provided some immediate benefits and, more importantly, will strengthen the foundation for future NAS services.

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

FAA relies on other federal agencies for weather services and support, especially NOAA's National Weather Service (NWS) and its Aviation Weather Center. Requirements validated by FAA for domestic and International Civil Aviation Organization (ICAO) users are coordinated annually and supported through the agencies and contractual arrangements. These partnerships are documented through the publishing of two documents--*The National Aviation Weather Program Strategic Plan* and *The National Aviation Weather Initiatives*. Each document was fully coordinated through the agencies and industry.

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

Technology. Aviation weather technology includes the ways in which aviation weather information is gathered, disseminated, and displayed. The development of this technology also demands that consideration be given to human factors and the application of decision-making tools. FAA will support the use of technology to improve

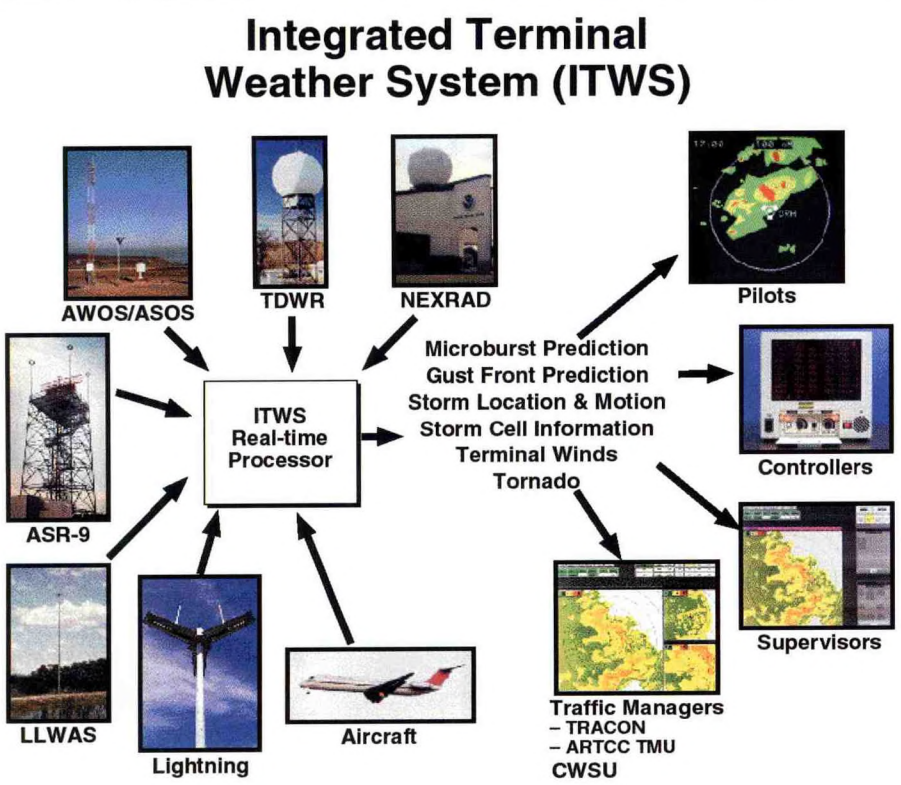


Figure 3-DOT-1. The ITWS will integrate data from FAA and NWS sensors and systems to provide a suite of weather informational products.

aviation weather information through integration of federal and non-federal resources. Automation, improved product generation, and dissemination to the cockpit offer early opportunities.

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

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

AVIATION WEATHER ACQUISITION AND SERVICES

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

Terminal Aviation Weather Programs

The Integrated Terminal Weather System (ITWS) will integrate weather data from sensors in the terminal area to provide and display compatible, consistent, real-time products that require no additional interpretation by controllers or pilots--the primary users. ITWS will use data from automated surface observing systems, Doppler weather radars, and low-level wind-shear alert systems, together with NWS data and products, to forecast aviation impact parameters, such as convection, visibility, icing, and wind shear, including down bursts. Initial capabilities will include sensors available now through the early years of the 21st Century. The development is now in the demonstration phase at several airports in various climatic regimes. There will be 34 ITWSs which will provide displays at 46 high activity airports that are supported by terminal Doppler weather radars. Full production is expected by the end of calendar year (CY) 2001 (Figure 3-DOT-1).

The Terminal Doppler Weather Radar (TDWR) program consists of the procurement and installation of a new terminal weather radar based on Doppler techniques. TDWR units will be located to optimize the detection of microbursts and wind shear at selected high activity airports. In addition, it will have the capability to identify areas of precipitation and the locations of thunderstorms (Figure 3-DOT-2).

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. TDWR scanning strategy will be optimized for microburst/windshear detection. The radar will be located near the airport operating areas in a way to best scan the runways as well as the approach and departure corridors. The displays will be located in the tower cab and Terminal Radar Approach Control (TRACON).

FAA has 41 TDWR systems commissioned and the remaining 4 systems will be commissioned by the end of CY 2002. A software upgrade which integrates TDWR and low level wind shear alert system data has been integrated at 9 high traffic/high weather threat airports

The Low Level Wind Shear Alert System (LLWAS) provides pilots with information on hazardous wind shear conditions that create unsafe conditions for aircraft landings and departures. A total of 110 airports have LLWAS. The 101 basic systems, LLWAS-2, consists of a wind sensor located at center field and 5 or more sensors near the periphery of the airport (Figure 3-DOT-3). A computer

processes the sensor information and displays wind shear conditions on a Ribbon display to air traffic controllers for relay to pilots. The improvement phase, referred to as LLWAS-Relocation/Sustainment (LLWAS-RS), will include expanding the network of sensors, developing improved algorithms for the expanded network, and installing new information/alert displays. The new information/alert displays will enable controllers to provide pilots with head wind gain or loss estimates for specific runways. These improvements will increase the system's wind shear detection capability and reduce false alarms. Improvements are also expected to reduce maintenance costs. Forty LLWAS–RS are scheduled to be deployed by CY 2001.

The Weather Systems Processor (WSP) program will provide an additional radar channel for processing weather returns and de-alias returns from the other weather channel in the ASR-9. The displays of convective weather, microbursts and other windshear events will provide information for controllers and pilots to help aircraft avoid those hazards. A prototype has been demonstrated and limited production has commenced. Full production deliveries are expected to be completed in 2002.

The Terminal Weather Information for Pilots (TWIP) program provides text message descriptions and character graphic depiction of potentially hazardous weather conditions in the terminal area of airports with installed TDWR systems. TWIP provides pilots with information on regions of moderate to heavy precipitation, gust fronts and microburst conditions. The TWIP capability is incorporated in the TDWR software application. Text messages or character graphic depiction are received in the cockpit through the Aeronautical Radio Incorporated (ARINC) Communication Addressing and Reporting System (ACARS) data link system. A total of 45 TDWR systems will be deployed with 41 of those currently installed and commissioned. The TWIP capability is operational at 31 of the TDWR sites. Activation of TWIP at the remaining sites is dependent on availability of NADIN II connectivity and program funding.

During FY 2000, the FAA Airborne Flight Information System (FIS) Policy will be implemented through Government-Industry Project Performance Agreements (G-IPPAs) with two industry FIS data link service providers (ARNAV Systems, Inc. and Honeywell International, Inc.). Through the government-industry agreements, the FAA provides access to four VHF channels (136.425-136.500) in the aeronautical spectrum while industry provides the ground infrastructure for data link broadcasts of text and graphic FIS products at no cost to the FAA. Under the agreements, a basic set of text products are provided at no fee to the pilot users while industry may charge subscription fees for other value-added text and graphic products.

The FAA FIS data link program will continue development of necessary standards and guidelines supporting inter-operability and operational use. In addition, the need and feasibility for

Figure 3-DOT-2. FAA Terminal Doppler Weather Radars provide supplementary wind and precipitation conditions for airport approach and departure.

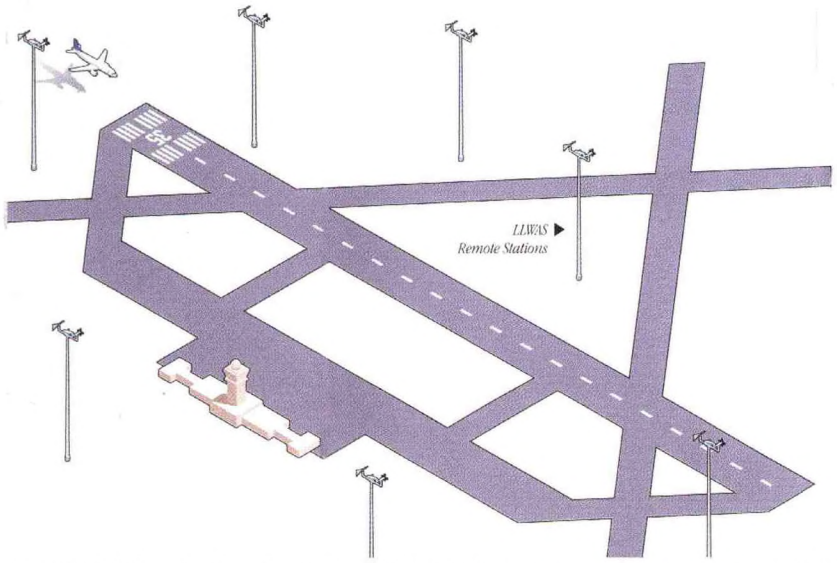


Figure 3-DOT-3. Artists drawing of LLWAS tower positions on an airfield.

establishing a national capability for collecting and distributing electronic pilot reports (E-PIREPs) from low-altitude general aviation operations will be evaluated. Also, in FY 2001 a concept analysis will be initiated to define the need for transition and evolution of FIS data link services supporting the future NAS architecture including Free Flight operations.

Surface Weather Observing Program

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

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

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

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

The FAA has negotiated with the National Oceanic and Atmospheric Administration (NOAA) to procure, install, operate, and maintain Automated Surface Observing Systems (ASOS) at the remaining airports where the FAA provides observations and at additional non-towered airports without weather reporting capabilities. A production contract was awarded in February 1991. The FAA has 568 systems installed and will have all commissioned by end CY 2000.

In a new program, funds were made available for 31 Aviation Weather Sensor Systems (AWSS). While they will have capability similar to ASOS, the AWSS is a direct acquisition of the FAA and not from the joint program. Full production will begin in FY 2001 with commissioning completed in FY 2002.

The AWOS/ASOS Data Acquisition System (ADAS) will function primarily as a message concentrator and will collect weather messages from AWOS and ASOS equipment located at controlled and non-controlled airports

within each air route traffic control center's (ARTCC) area of responsibility. ADAS will distribute minute-by-minute AWOS/ASOS data to the Weather and Radar Processor (WARP) within the air route traffic control center in which it is installed. ADAS will also distribute AWOS data to the National Airspace Data Interchange Network (NADIN) which will in turn forward the data to Weather Message Switching Center Replacement (WMSCR) for further distribution. Field implementation of ADAS has been completed.

Automated Lightning Detection and Reporting System (ALDARS). ALDARS is a system adjunct to the ADAS. It collects lightning stroke information from the National Lightning Detection Network (NLDN) and disseminates this data to AWOS/ASOS for the reporting of thunderstorms in METAR or SPECI observations, when appropriate. The use of ALDARS eliminates the need for manual reporting of thunderstorms and increases the number of airports where thunderstorms will be reported.

Stand Alone Weather Sensors. These sensors are planned to be back-up for some AWOS/ASOS sensors at locations where no other back-up capability is available. Full delivery is expected by CY 2001.

AWOS for Non-Federal Applications. Under the Airport Improvement Program (AIP), state and other local jurisdictions may justify to the FAA their need to enhance their airport facilities. Upon approval, these improvements may be partially funded by the FAA using resources from the Airway Trust Fund. The local airport authority becomes responsible for the remainder of the funding necessary to complete the procurement as well as the funding for the regular maintenance. The addition of an AWOS is one of the improvements that qualify for AIP funding assistance. Systems that qualify must meet certain standards which are defined in an FAA Advisory Circular on Non-Federal Automated Weather Observing Systems.

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

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

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

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

A total of 528 RVR visibility sensors will be deployed at 264 airports. Delivery of the new RVR sensors began in November 1998. Sixty new RVRs have been fielded with the rest expected by the end of CY 2001. Enhancements are planned to interface with the control tower and the ASOS by mid 2000.

En Route Aviation Weather Programs

The FAA is procuring the Operational and Supportability Implementation System (OASIS) to improve weather products, flight information, aeronautical data collection, analysis, and timeliness of dissemination and, thereby, enhance the safety and efficiency of the NAS. OASIS will replace the Model-1 Full Capacity Flight Service Automation System, which includes the Aviation Weather Processor. OASIS will also integrate the Interim Graphic Weather Display System functions and include several automated flight service data handling capabilities. This configuration will be its initial deployment capability. Operational testing began in 1999; full deployment will commence in FY 2001.

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

The Next Generation Weather Radar (NEXRAD), known operationally as the Weather Surveillance Radar-1988 Doppler (WSR-88D), is a multi-agency program that defined, developed, and implemented the new weather radar. Field implementation began in 1990 and was completed in 1996. There are a total of 161 WSR-88D systems deployed. The FAA sponsored 12 systems in Alaska, Hawaii, and the Caribbean. DOC and DOD WSR–88Ds provide coverage over the continental United States.

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

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

The Air Route Surveillance Radar (ARSR-4) provides the ARTCCs with accurate multiple weather levels out to 200 nautical miles. The ARSR-4 is the first en route radar with the ability to accurately report targets in weather. The ARSR-4 can provide weather information to supplement other sources. The ARSR-4 is a joint FAA/USAF funded project. Forty joint radar sites were installed during the 1992-1995 period.

Aviation Weather Processing Programs

The Weather and Radar Processor (WARP), Stage 0 has replaced the Meteorologists Weather Processor to provide aviation weather information to the Center Weather Service Units. Stage 1 and 2 will automatically create unique regional, WSR-88D-based, mosaic products, and send these products, along with other time-critical weather information, to controllers through the Display System Replacement and to pilots via the FIS. WARP will greatly enhance the dissemination of aviation weather information throughout the NAS. WARP is currently undergoing operational testing and evaluation and will be fielded at the ARTCCs in CY 2000 and early 2001

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

AVIATION WEATHER COMMUNICATIONS

It should be noted that FAA communications systems are multi-purpose. Weather data, products, and information constitute a large percentage of the traffic, as do NOTAMS, flight plans and other aeronautical data. The National Airspace Data Interchange Network (NADIN II) packet-switched network was implemented to serve as the primary inter-facility data communications resource for a large community of NAS computer subsystems. The network design incorporates packet-switching technology into a highly connected backbone network, which provides extremely high data flow capacity and efficiency to the network users. NADIN II consists of operational switching nodes at two network control centers (and nodes) at the National Aviation Weather Processing Facilities at Salt Lake City, Utah, and Atlanta, Georgia. It will interface directly to WMSCR, WARP, ADAS, TMS, and the Consolidated NOTAM System. NADIN II also may be used as the intra-facility communications system between these (collocated) users during transition to end state.

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

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

responsibility for dissemination to the entire network.

Currently, specifications for an upgrade or replacement for the WMSCR are being formulated. The needs, when developed, will be entered into the AMS process for validation and acceptance into the NAS architecture.

The Flight Information Service (FIS) is a new communications systems to provide weather information to pilots in the cockpit. FIS is a partnership program among the government and private industry with the government providing the base information and the bandwidth while the private companies provide the broadcast and value-added products. New products are screened for technical suitability and value to the pilots.

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

Two of the three satellites are funded by the United States. The first is located over the western Atlantic with a footprint covering western Africa and Europe, the Atlantic Ocean, South America, and North America (except for the West Coast and Alaska). The second United States-funded satellite is positioned over the Pacific and covers the United States West Coast and Alaska, the Pacific Ocean, and the Pacific rim of Asia. The third satellite, operated by the United Kingdom, is stationed over the western Indian Ocean and covers the remaining areas of Europe, Asia, and Africa. The data available via WAFS include flight winds, observations, forecasts, SIGMETs, AIRMETs, and hazards to aviation including volcanic ash clouds.

AVIATION WEATHER RESEARCH PROGRAM

Working closely with the Integrated Product Team for Weather/Flight Services Systems, ARW sponsors research on specific aviation weather phenomena which are hazardous and/or limiting to aircraft operations. This research is performed through collaborative efforts with the National Science Foundation (NSF), the NOAA, the NASA and the Massachusetts Institute of Technology's Lincoln Laboratory. A primary concern is the effective management of limited research, engineering, and development resources and their direct application to known deficiencies and technical enhancements.

Improved Aircraft Icing Forecasts. The purpose of this initiative is to establish a comprehensive multi-year research and development effort to improve aircraft icing forecasts as described in the FAA Aircraft Icing Plan. The objectives of this plan are to develop: (1) an icing severity index, (2) icing guidance models, and (3) a better comprehension of synoptic and mesoscale conditions leading to in-flight icing. The result of this effort will be an improved icing forecasting capability that provides pilots with more timely and accurate forecasts of actual and expected icing areas by location, altitude, duration, and potential severity.

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

Model Development and Enhancement. This research is aimed at developing or improving models to better characterize the state of the atmosphere and stratosphere in general, with specific emphasis on the flight operation environment specifically, with the aim to provide superior aviation weather products to end users.

Aviation Gridded Forecast System (AGFS). The Product Development Team (PDT) for AFGS is working on the development of products for dissemination on the Aviation Digital Data System. New algorithms will be developed to present hazardous conditions in the flight operations environment. They will develop a process for automated production of the SIGMETs.

Weather Support to Deicing Decision Making (WSDDM). This system develops products that provide forecasts on the intensity of snow and freezing rain, and how or when these phenomena will change in the short term. This information is needed by airport management to determine when an aircraft will require deicing before take-off. The water content of snow is believed to be an important factor. The output product is designed for non-meteorological aviation users and has been demonstrated at three different airports. Development work has been completed and FAA has made this system available to airport authorities who wish to use it as a decision aid.

Ceiling and Visibility. A development and demonstration is underway in the San Francisco Bay area. The project will have unique sensors, the data from which will be used in new algorithms to develop new and improved forecasts. The project will

continue over a number years as the progress is evaluated. This project is joint effort with other Federal agencies and some of the effort is performed by academic researchers.

Turbulence. In addition to the work being performed by the Joint Safety Analysis Team under the Safer Skies Program, a PDT has a seven year plan to evaluate wind shear and turbulence around and on the approaches to Juneau, Alaska. Also, they are working with certain airlines to install instruments on aircraft with the capability to measure turbulence as sensed on the aircraft and report this information automatically. The data will be used to verify forecasts and to develop a standard index to report and warn for turbulence.

NEXRAD Enhancements. Work is continuing to develop improvements to the existing products and to develop some new graphics. Hardware and software pre-planned product improvements are are being pursued. These efforts are joint among DOT, DOD and DOC.

FEDERAL PROGRAMS IN SUPPORT OF ROAD WEATHER

Strategic Highway Research Program

The Strategic Highway Research Program (SHRP) was established by the United States Congress through the1987 Highway Act. In this Act, the Federal government obligated $150 million over five years to improve the performance and durability of our nation's roads and to make those roads safer for both motorists and highway workers. The SHRP program examined a number of different subject areas, with the winter maintenance efforts falling under the highway operations subject area. Products from this program include specifications, testing methods, equipment, and advanced technologies.

Following the success of this initial, 5-year effort, the FHWA took on the task of coordinating a national program to work with state and local highway agencies to effectively implement and evaluate these products. This phase, entitled SHRP Implementation, was funded through the 1991 Highway Act, entitled the Intermodal Surface Transportation Efficiency Act. This Act obligated $108 million over six years, and was administered by a joint effort between the FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board.

Intelligent Transportation Systems

While the SHRP program was underway, the Department of Transportation (DOT) was also investing in a significant program aimed at implementing technologies for a host of other transportation challenges, namely the Intelligent Transportation System (ITS) program. Of the many goals of the ITS program, one is to coordinate and deploy some of the SHRP products involving communications and control in winter maintenance. Such implementations are guided by the National ITS Architectures, which provides the framework for road weather system design and information exchange. The development of ITS in the United States is overseen by the ITS Joint Program Office (ITS-JPO) within the DOT.

Development of Road Weather Information Systems

The efforts following SHRP, as well as the results of the ITS program, have resulted in a host of improvements to treatment of and response to weather in surface transportation. Many of these improvements have been fully evaluated, while others are still evolving or under going further evaluation.

Road Weather Information Systems (RWIS)

SHRP and other FHWA or State DOT programs have identified the cost-effectiveness of anti-icing - the pretreatment of roads for better snow removal and ice control. Anti-icing relies heavily on Road Weather Information Systems (RWIS), which include the development of weather products specifically aimed at the highway community. RWIS initially referred only to the fixed roadside sensor suites for pavement condition (temperature, chemical concentration, surface ice/snow/water) and surface weather observations (temperature, winds, relative humidity, visibility and precipitation). Over time, RWIS has broadened to include all weather-information sources used in road maintenance. Consequently, the more precise term for the sensors, both fixed and mobile, is the Environmental Sensor Station (ESS). The ITS program, which is based on open system principles, has drafted a standard around ESS observations. The ESS standard defines protocols for data passage from the roadside to a central processing unit. Figure 3-DOT-4 reflects the widespread deployment of ESS throughout the United States. But this observing network is thin, with about 1,200 remote units to cover 4 million highway route miles. Techniques such as thermal mapping or use of ESS with heat valve models are necessary to extend coverage of road condition information.

Advanced Transportation Weather Information System (ATWIS)

Federally supported projects stemming from the first generation SHRP RWIS projects have been important in

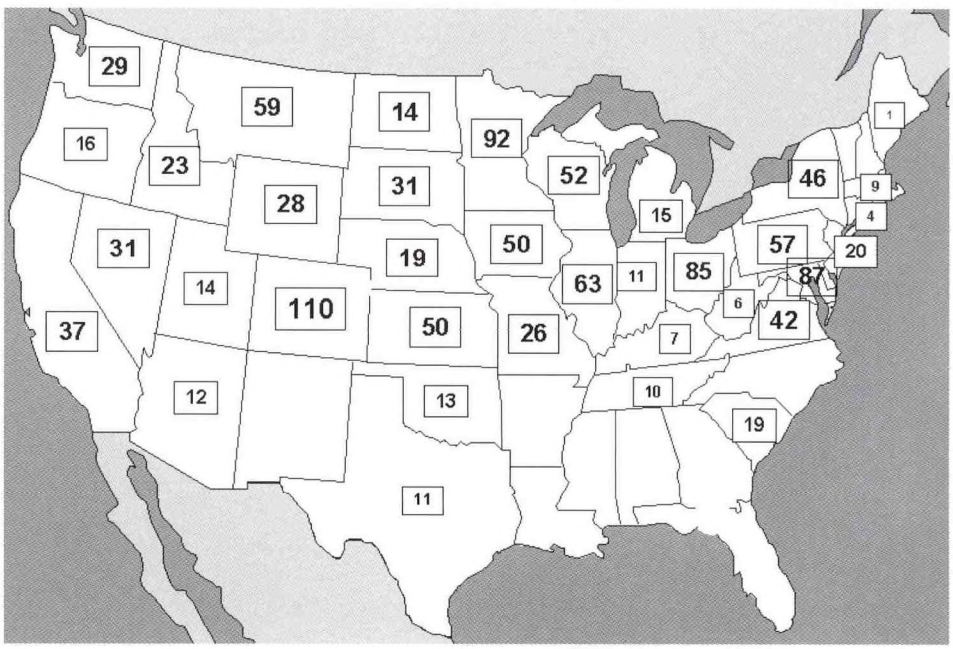


Figure 3-DOT-4. Pavement and ESS Technology Deployment.

Weather Information for Surface Transportation
"The Highway Environment"

Weather significantly impacts highway operations across the United States, resulting in added costs, impaired safety and all too often resulting in catastrophic incidents. In December of 1990, fog contributed to a devastating crash in which reduced visibility was a major contributor to a 99-vehicle pile up in Calhoun, Tennessee. The incident resulted in 12 deaths and 44 injuries. More recently, west of Denver on November 22, 1999, two people were killed and 29 others were injured in two massive Interstate 70 pileups due to fog and ice. Enhanced road weather information can assist in avoiding such tragic events.

The impact of adverse weather continually influences the day-to-day operations of our nation's roadways. Be it a snow storm, ice on the pavement, rain, flooding, fog, dust, wind, hurricanes, or tornadoes, the users of the transportation system (including commercial vehicle operators, long distance travelers, transit operators, commuters, etc.) are impacted by delays, crashes, and reduced pavement level of service. Weather affects the visibility, tractability, maneuverability, vehicle stability, exhaust emissions and structural integrity of the surface transportation system. These factors in turn affect the safety, mobility, productivity and environmental quality of the system.

It has been estimated that a one-day highway shutdown due to snow costs a metropolitan area between $15 million and $76 million in lost salaries, sales, and taxes. Clearly weather is one of the most costly types of incidents on the highway system, with significant economic and quality of life impacts. Managing these incidents is also costly, with system operators spending significant amounts of time and money to keep the system running smoothly. It is estimated that at least $2.0 billion is spent per year in the United States on snow and ice control alone, and $5.0 billion is spent per year repairing weather-related infrastructure damage. While the indirect costs are not as well documented, they are no less significant. There are about 7,000 fatal crashes and 450,000 injury crashes each year that occur during adverse weather. In addition, the delays to travelers due to reduced capacity are substantial, though very difficult to quantify.

Previous efforts in the areas of weather and winter mobility have demonstrated that these costs can be reduced, through weather information systems that are tailored to the surface transportation environment. However, to date most of these efforts have been designed for a subset of the population (i.e., for winter maintenance purposes only), and are not well integrated with other traffic management and traveler information systems. Furthermore, they have been built independent of the larger meteorological community. So despite the wealth of weather information currently available, this information is either insufficiently presented, or is inadequate or inappropriate for the types of transportation decisions being made. Consequently, the challenge is to develop integrated weather information systems that meet the decision making needs of all users and operators, and to do so in a manner that is based on the open exchange of information, and builds upon recent transportation and meteorological advancements. This is the vision of the Federal Highway Administration (FHWA) Road Weather Management program.

developing route-specific road condition information. The Advanced Transportation Weather Information System (ATWIS) was developed by the University of North Dakota for North and South Dakota, and the system has recently expanded into Minnesota and Montana. The primary purpose of the ATWIS research program is to demonstrate how current technologies in weather forecasting, weather analysis, telecommunications and road condition monitoring can be merged effectively to produce a safer and more efficient transportation system for both commercial and general travel. ATWIS operates its own meso-scale numerical model, analyzed to road conditions on segments of the Interstate freeway and arterial system in its states. Information is conveyed interactively to travelers, primarily via cell phone.

Key areas of interest of this study include:

- public use and acceptance of road weather information,
- the added value of highly accurate weather forecasts,
- information dissemination methods, and the role of telecommunications,
- the need for 24-hour operations,
- the role of road condition monitoring,
- how to generate efficient forecasts, and
- commercial viability of the system.

ATWIS teams public and private partners to meet the immediate and future needs of rural transportation. As a dynamic Information Service Provider, University of North Dakota's Regional Weather Information Center operates a Transportation Management Center, collecting, analyzing, and providing weather and road condition information to the general public, and State Departments of Transportation (DOT).

FORETELL

With the intent of integrating RWIS with other ITS services, the FORTELL project was initiated by federal, state and private funds, in Iowa, Missouri, and Wisconsin. Developing similar capabilities as seen in the ATWIS project, FORETELL focuses more on detailed decision support for road maintenance and the development of heat balance algorithms in combination with its meso-scale numerical modeling. FORETELL is a consortium made up of federal, State, research agencies, and private sector partners from diverse ITS and meteorological backgrounds, that share the common resolve to see detailed road and weather information become an everyday commercial reality.

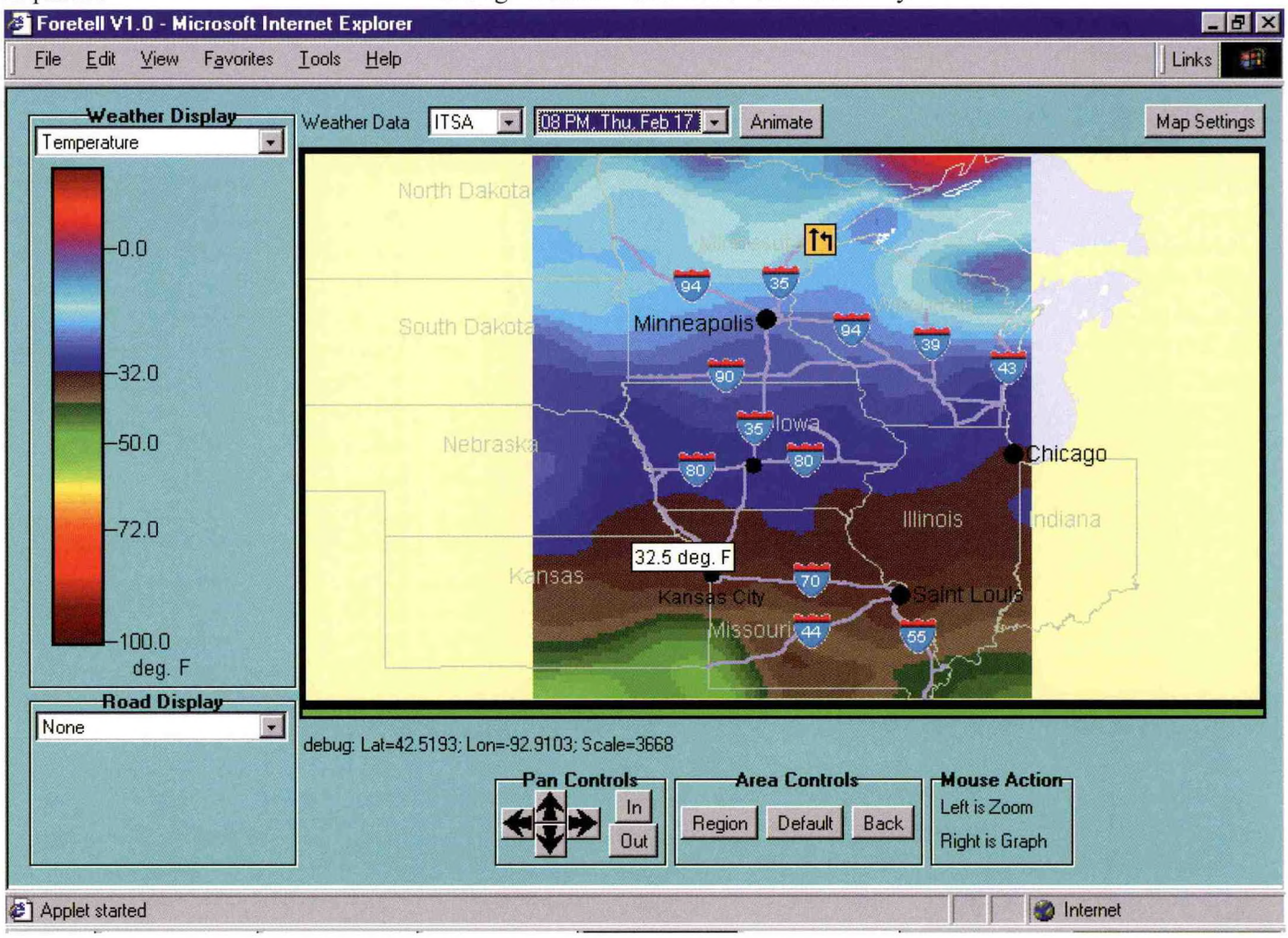


Figure 3-DOT-5. Display of FORETELL Interactive Website

FORETELL enhances safety and facilitates travel by linking road condition information with other types of traveler information (e.g. incidents, work zones, road closures, etc).

FORETELL's objectives and benefits include:

- integrating RWIS across State borders,
- assimilating all of the existing weather and road condition data sources,
- cutting costs and substantially benefiting the environment by increasing the levels of forecasting detail,
- improving timeliness and the accuracy of road weather information, and
- using multiple media for information dissemination.

FORETELL is based on an open-system architecture, which enables ease in evolution and information presentation. Figure 3-DOT-5 displays information located on the FORETELL interactive website. Accidents, road closures, congestion, weather conditions, delays, lane closures, current weather conditions are among the many types of information displayed on the website.

Nationwide Expansion of Road Weather Information

Early results from field operational tests and other experiences have demonstrated encouraging benefits of utilizing technology to develop road weather information. As these systems evolve, a clear pattern of regional services is emerging.

Figure 3-DOT-6 reflects these regional road weather information systems across the United States ranging from the I-95 Corridor Information Exchange Network (IEN) project to RWIS in Washington State (sponsored by Washington DOT and the University of Washington). Also included is the Highway Closure and Restriction System (HCRS) developed by Arizona DOT, as well as the traveler information system entitled Condition Acquisition and Reporting System (CARS), which built upon the FORETELL project. Other projects include the ATWIS project in North and South Dakota and Minnesota, the Safe Passage project in Montana, the Utah DOT and University of Utah mesonet project, the Southeastern Michigan Snow and Ice Management (SEMSIM) project located in the Detroit the metropolitan area, the OK-First project in Oklahoma, and the Virtual Traffic Management Center in Texas. The Intelligent Road and Rail Information System (IRRIS) is a motorist information system for military movements that is working with Texas to obtain dynamic road condition information. This figure raises a number of questions, for example: (1) should these regional developments limit their geographic scope or should they continue to expand and overlap? (2) how do we ensure that a person driving from one service area to another is able to obtain consistent information? (3) what are the appropriate public and private weather information rates? (4) how can different road condition models be reconciled or combined?

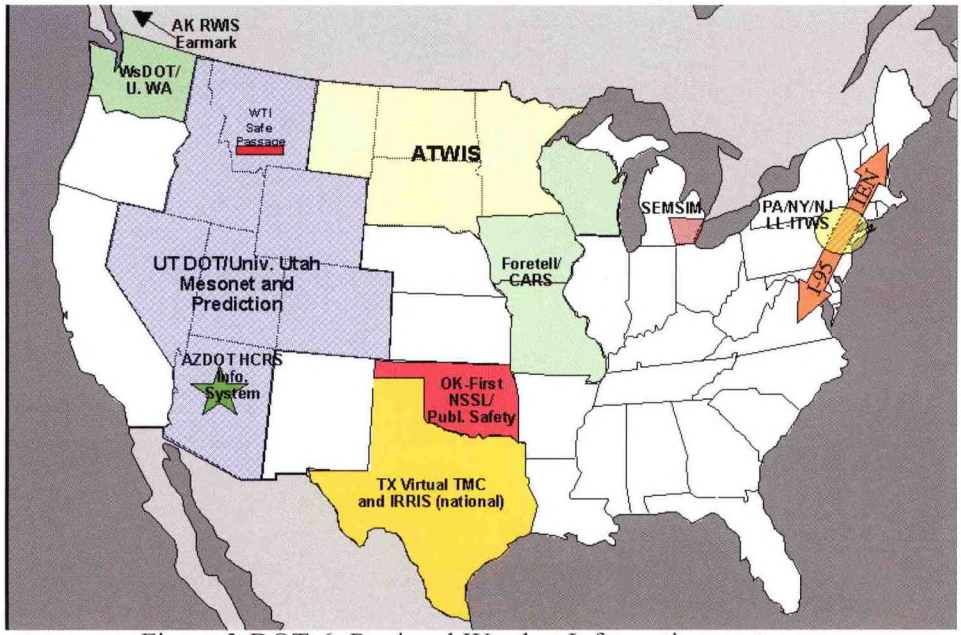


Figure 3-DOT-6. Regional Weather Information systems.

Current Benefits

The cost savings for a state's highway winter maintenance operations have been achieved in the reduction of personnel overtime costs and decreased use of deicing chemicals and abrasives. For example, Minnesota DOT has calculated a 6:1 to 10:1 return on investment in RWIS for winter maintenance practices. Likewise, RWIS and anti-icing has lead to cost-savings for Wisconsin DOT--the use of RWIS and anti-icing has reduced salt use by 37,500 tons over one season. This reduction equates to approximately $1.1 million saved.

Another example of winter maintenance costs saving was in the state of Indiana, the implementation of the Computer Aided System for Planning Efficient Routes (CASPER). The software is used to assist with the design of routes needed to service the roadway networks based, in part, on road weather conditions. Developers estimate that the equipment and operating cost for winter maintenance has been reduced between $11 million and $14 million.

FHWA's Road Weather Management Program

The FHWA continues to make road weather management a priority in their

transportation operations program. As described earlier, a significant amount of federal dollars have been invested over the course of the last 13+ years. Recent expenditures, on the order of $2 million/year, have also represented a commitment to this program. However, this expenditure represents only a fraction of the amount of money spent on road weather, as the state and local agencies fund a number of their own research and development projects. Such achievements and ongoing efforts are fundamental to achieving our vision, while the goals of the program in support of our vision have been defined as: (1) to develop improved road weather information systems that meet the demands of all users and operators; (2) to develop improved tools and technologies for road weather management and winter maintenance; and (3) to improve traffic operations/incident management procedures for all types of weather events.

By providing weather information that is more accurate and easily understood, outcomes of improved mobility, safety, and productivity will be achieved.

There are many program efforts that need to take place to achieve these goals, and FHWA is central to most of these, either as developer, coordinator, or promoter. The following objectives have been identified in an effort to achieve our goals over the next five years:

- At a national level build consensus and continue to strengthen the relationship between meteorologists and transportation professionals thus providing the leadership for state efforts and creating a common vision for the overall program design.
- Provide improved weather information by developing decision support systems that use better processed weather data and improved weather observation networks to furnish information that is easily interpreted and that adequately combines all types of information that is required to make informed decisions.
- Develop advanced maintenance technologies that are designed to meet the needs of maintenance personnel.
- Develop road weather management practices that define the approach in which traffic and incident managers optimize the performance of their system.
- In coordination with current federal programs such as Professional Capacity Building, Local Technology Assistance Program, etc., develop outreach and training course material for program delivery, training, and promotion.

Current and Future Efforts

A number of other research efforts have been completed or are underway to reach our goals and objectives. Perhaps the most significant is our effort to document the road weather decision support requirements needed by end users to support more effective decision making. Such an effort has never been done before, yet is fundamental to all research, development, and testing efforts. Other ongoing efforts include the prototyping of a low cost visibility sensor for the highway environment, and remote sensors for detecting ice on pavements. The FHWA has also worked with our partners to test and evaluate systems that automatically control anti-icing sprayers on bridge decks. As previously mentioned, FHWA has also been instrumental in the field operational test called FORETELL, which is developing and evaluating a weather information system that integrates advanced road weather prediction with other types of traveler information.

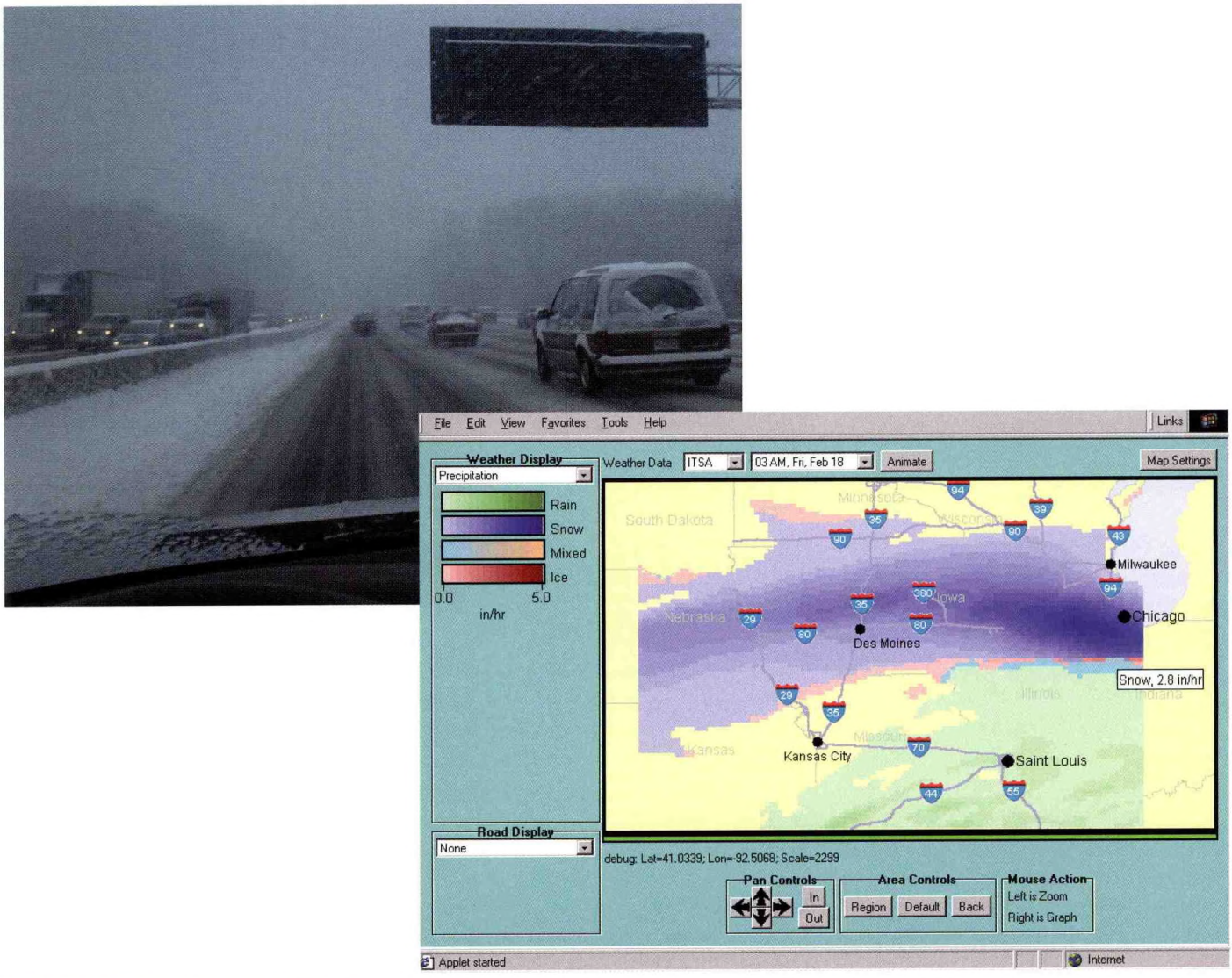
Future efforts will focus on all technical aspects of the road transportation system, including weather data collection, processing and dissemination, as well as the institutional challenges surrounding system implementation. The institutional challenges include coordination within state and local DOT, such as between maintenance and travel management offices, as well as across the transportation and meteorological communities. With regard to technical areas of interest, data collection efforts will include optimizing the siting of environmental sensor stations, as well as incorporating road weather observational data, such as pavement and subsurface observations, into broader meteorological observation networks. Better processing includes the application of higher resolution weather models, and the development of other road condition prediction models (e.g. heat balance models) that are needed to develop the appropriate weather information. Such products will be incorporated into better decision support systems, whose design is based on the current efforts to document road weather decision support requirements. Development of such systems requires strong inter-federal coordination between the transportation and meteorological communities. Finally, the FHWA will continue to develop outreach and training course material for program delivery, training, and promotion.

With respect to implementation, it is important to note that unlike the FAA, FHWA is not a modal operating agency, and it represents many constituents, such as state, cities and local governments. FHWA will take the lead in initiating efforts, such as defining road weather decision support requirements, and prototyping decision support systems. However, the success of this program largely depends on the efforts of the operating agencies, as well as the coordination across the transportation and meteorological communities. Therefore, it is expected that the results of these efforts will lead the owners and operators of the nation's highways, the State and local DOT, to invest in the implementation of these systems nationwide.

National Coordination

In order to achieve the maximum benefit and desired output from this program area there must be a mutual interest and commitment across the transportation and meteorological communities. Currently, efforts to develop weather information systems for surface transportation are moving forward. These efforts are complicated by the need for significant coordination between the transportation and meteorological communities--to date the two communities have had little direct interaction on a national level. As this working relationship builds, it has become evident that the meteorological community must have a clear idea of the surface transportation weather requirements in order to respond with the appropriate products and services. Consequently, the transportation community must articulate it's needs, and in a manner that enables the meteorological community (both public and private) to respond. Likewise, the meteorological community must be committed to helping resolve the problems that weather inflicts upon the surface transportation system.

Continued national-level consensus building will be necessary both to provide leadership for state efforts and to create a common vision for the overall program design. It is important to coordinate our efforts with others, as it ensures that we are not duplicating effort, while also keeping our goals and objectives focused on the needs of our constituents. The most apparent groups to link to include: Federal, State and local agencies both in the transportation and meteorological communities, standards groups, and national committees and associations dealing with surface transportation weather and winter mobility. To date there have been same significant achievements, such as the formation of the OFCM Joint Action Group for Weather Information for Surface Transportation (JAG/WIST), and FHWA--FEMA coordination for hurricane evacuation. However, this is only considered the first of many successful partnerships. The FHWA looks forward to building upon these successes to achieve the needed improvement to the highway environment.



Although no United States Coast Guard (USCG) cutters or shore units are solely dedicated to meteorology, they collectively perform a variety of functions in support of the national meteorology program. USCG ocean-going cutters and coastal stations provide weather observations to the National Weather Service (NWS). Coast Guard communications stations broadcast NWS marine forecasts, weather warnings, and weather facsimile charts and, also, collect weather observations from commercial shipping for the NWS. The Coast Guard also operates the LORAN C radionavigation system and the Maritime Differential GPS (DGPS) Service. The LORAN C system provides Position, Navigation, and Timing (PNT) information to a variety of navigation and non-navigation users throughout the continental United States and Alaska (e.g. radiosondes). The Maritime DGPS Service is an augmentation to the GPS that improves GPS-only accuracy to better than ten meters and provides DGPS coverage to coastal areas of the continental United States, the Great Lakes, Puerto Rico, portions of Alaska and Hawaii, and portions of the Mississippi River Basin.

USCGC HEALY, a new icebreaking research vessel, was delivered to the Coast Guard in November 1999 and is undergoing shakedown tests of the hull, machinery, and scientific equipment (Figure 3-DOT-7). The first unrestricted science cruise is anticipated for 2001. HEALY, has a length of 420 feet, beam of 82 feet, and displaces over 16,000 tons. Scientific systems and gear include a bottom mapping multi-beam sonar system; a sub-bottom profiling system; a conductivity-depth-temperature data system; an expendable oceanographic probe system; an Acoustic Doppler Current Profiler; a jumbo coring system; a continuous flow, seawater sampling system; a meteorological measurement system; and a bow tower for clean air experiments. To schedule time on HEALY, see the UNOLS web site, *http://gso.uri.edu/unols/unols.html*. For more information, see the Coast Guard web page for HEALY, *http://www.uscg.mil/pacarea/healy/*.

Figure 3-DOT-7. USCGC HEALEY, the Coast Guard's new icebreaking research vessel, conducting ice trials.

USCG maintains the International Ice Patrol (IIP) which uses sensor-equipped aircraft to patrol the Grand Banks of Newfoundland to locate and track icebergs which pose a hazard to North Atlantic shipping. Direct observations are supplemented and extrapolated using a numerical iceberg drift and deterioration model. IIP determines the geographic limits of the iceberg hazard and, twice daily, broadcasts iceberg warning bulletins and ice facsimile charts which define the limits of the iceberg threat during the iceberg season (spring and summer). IIP annually archives data on all confirmed and suspected targets, and forward these data to the National Snow and Ice Data Center. These data can be accessed via the IIP web page *www.uscg.mil/lantarea/iip/home.html*. Archived data contains all iceberg sighting data along with the last model-predicted position of each berg.

The Coast Guard participates with the Navy and NOAA in conducting the National Ice Center, a multi-agency operational center that produces analyses and forecasts of Arctic, Antarctic, Great Lakes, and coastal ice conditions.

The Coast Guard also collaborates with NOAA in operating the National Data Buoy Center (NDBC) which deploys and maintains NOAA's automated network of environmental monitoring platforms in the deep ocean and coastal regions. Twelve Coast Guard personnel fill key technical and logistics support positions within NDBC, with the senior Coast Guard officer assigned serving as the NDBC Deputy Director Coast Guard cutters support the deployment and retrieval of data buoys, and provide periodic maintenance visits to both buoys and coastal stations, expending approximately 180 cutter days annually. Coast Guard aircraft, small boats, and shore facilities also provide NDBC support.

Meteorological activities are coordinated by the Icebreaking Division of the Office of Aids to Navigation at Coast Guard Headquarters. Field management of Coast Guard meteorological support services is accomplished as the Coast Guard Area and District levels.

DEPARTMENT OF AGRICULTURE WEATHER PROGRAMS

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

METEOROLOGICAL PROGRAMS

The World Agricultural Outlook Board (WAOB), in cooperation with National Weather Service's (NWS) Climate Prediction Center, staffs and supports the Joint Agricultural Weather Facility (JAWF). The JAWF monitors the daily weather patterns around the world, and serves as the Department's focal point for weather data received from the World Meteorological Organization's (WMO) Global Weather Observing System. These data are used at JAWF and other USDA agencies for a number of agricultural applications. WAOB agricultural meteorologists convert the weather data into information to assess crop development and yield potential of all major commodity crops for the major producing areas of the world. Special weekly briefings are provided to the Secretary of Agriculture and to the economic and commodity analysts of USDA. The Senate and House Agricultural Committees also request periodic agricultural weather briefings that focus on the severity and impact of drought, heat wave, and excessive wetness on major crop areas around the Nation.

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

Currently, the FS operates more than 900 RAWS and manual stations, many in the western United States. Air temperature, relative humidity, soil moisture, wind direction and speed, and precipitation are transmitted via NOAA's Geostationary Operational Environmental Satellite (GOES) telemetry. These data are received via a direct-readout ground site in Boise, Idaho, in cooperation with the Bureau

Figure 3-USDA-1. Forest Service meteorological programs include supporting firefighting activities during summer fire season.

of Land Management. The main use of the data is in the calculation of the fire danger rating for the FS and cooperating agencies. These data are also used by other resource managers, such as, road engineers, wildlife biologists, and hydrologists who monitor precipitation; silviculturalists (who are attempting to maximize tree-planting opportunities); and ecologists, soil specialists, and fisheries biologists (who monitor the effects of runoff). Another major user of RAWS data is the NWS for fire weather forecasting and flood warnings.

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

Water-supply forecasts help irrigators make the most effective use of available streamflow for achieving their agricultural production goals. Farmers, who collectively irrigate more than 10 million acres of land in the western United States, benefit from these 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.

NRCS continues to upgrade the SNOTEL data collection system. The effort includes upgrading the data collection sites in the existing SNOTEL system with new state-of-the-art equipment and adding additional sites. The data collection site upgrades include replacement of snow pillows, transducers, damaged precipitation gages, antennas, towers, solar panels, battery temperature sensors, and deteriorated shelter houses.

The Foreign Agricultural Service's (FAS) satellite remote-sensing program, operated by the Production Estimates and Crop Assessment Division (PECAD), is a critical element in USDA's analysis of global crop conditions and agricultural production providing timely, accurate, and unbiased estimates of global area, yield, and production. The PECAD mission of alert analysis requires rapid system response. Working in conjunction with the Farm Services Agency (FSA), PECAD provides alerts as well as routine crop condition assessments for crops in the United States. FAS provides early warning of environmental changes that affect the production and quality of commodities and renewable resources. PECAD is the world's most extensive and longest running (20 years) operational user of commercial satellite data for crop condition assessments, using numerous satellite platforms.

The FAS/PECAD analysts employ a proven "convergence of evidence" approach to crop assessment -- incorporating NOAA AVHRR, LandSat, and SPOT imagery, crop models, global weather data, United States agricultural attache reports, field travel, and ancillary data to forecast foreign grain, oilseed, and cotton production. To complement the remote sensing image data sets, weather data are also processed from 6,912 of the United Nations' WMO stations and from approximately 88,500 grid cells of the Air Force gridded weather data are processed on a daily basis. Crop models are based on daily data loaded from meteorological stations and/or Air Force gridded weather data. Some models add Vegetative Index Number (VIN) information. The goal of a crop model is to provide a number that can be quantified to yield per acre.

FAS/PECAD routinely forecasts global grain production to within roughly 3 percent of final output. FAS remote sensing supports Department of State assessments of food needs as situations arise. FAS prepares detailed analyses of global weather events, such as drought in Ukraine, dryness in China and North Korea, and flooding in Mexico and Central America. PECAD also provides in depth coverage of significant crop developments in specific countries, including the 1999 record Argentine soybean crop, bumper wheat crop in Australia, and bumper soybean crop in Brazil.

The Farm Service Agency (FSA), continued to share with FAS the cost of analyzing imagery of the United States. Timely analysis of United States crop conditions, combined with weather data, crop model results, and GIS products made possible the development of accurate and timely projections and comprehensive evaluations of crop disaster situations. During the 1999 growing season in the United States, the domestic analysts of FAS/PECAD provided early warning on anomalous crop conditions, including the severe droughts in the Mid-Atlantic States and Eastern Corn Belt as well as flooding from hurricanes and subsequent rainfall in North Carolina and southern Virginia. The impact of the sixth consecutive wet spring and early summer on agricultural interests in North and South Dakota was determined and reported in interagency briefings and published on the internal FSA/FAS web-site. FSA continued to be a partner in the National Aerial Photography Program (NAPP) and National Digital Orthoquad Program (NDOP). FSA started to field re-engineered business processes that combine the use of digital orthophotography, GIS, GPS, and satellite imagery to replace the use of hardcopy NAPP aerial photography and 35mm slides.

SUPPORTING RESEARCH

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

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

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

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

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

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

DEPARTMENT OF ENERGY OPERATIONAL AND RESEARCH WEATHER PROGRAMS

For nearly 50 years, the Department of Energy (DOE) and its predecessors, the Atomic Energy Commission and the Energy Research and Development Administration, have established and supported meteorological operations and atmospheric research at the DOE field offices. The need for meteorological services began in 1944 with the development, fabrication, and testing of atomic weapons and the national security and safety issues associated with them. Meteorological program requirements were subsequently augmented by the passage of environmental protection legislation, which is enforced by the Environmental Protection Agency (EPA), and by several DOE Orders that specify requirements for meteorological services to protect public health and safety and the environment.

The Department of Energy (DOE) continues to address its mission areas of national security, science and technology, energy security, and environmental quality. Atmospheric science research and operations have been an integral part of DOE and its predecessor agencies since the cold war era. It is vital to understand the nature of the atmospheric domain with its various dynamic and chemical aspects of energy-related phenomena and how it interacts with the ocean and terrestrial domains. Today's global climate change debates and outcomes are relying on information collected through basic atmospheric science research programs that one day will reduce substantial uncertainties in these areas.

DOE coordinates programmatic activities throughout its various offices, such as Defense Programs (DP), Science (SC), Environmental Management (EM), and Energy Efficiency and Renewables (EE). Some of these program offices are responsible for the management of scientific research programs, such as the Atmospheric Release Advisory Capability (ARAC), Global Climate Change Research (GCCR), and various clean up activities at former production sites.

Meteorological services at DOE facilities range from cutting-edge basic research to providing daily operational support. Some examples of research and development are investigations of potential global climatic change, radiation and cloud studies, and studies of atmospheric boundary layer processes. Operational support programs include daily customized weather forecasting services, special project support, on-site meteorological monitoring programs, climatology services, and emergency response program support. Some DOE sites maintain 24-hour weather watches for severe weather conditions that could impact site operations, damage property, or threaten lives.

Several DOE field offices and their associated sites and facilities, such as Idaho National Engineering and Environmental Laboratory (Idaho Falls, Idaho), Oak Ridge Reservation (Oak Ridge, Tennessee), Nevada Test Site (Las Vegas, Nevada), Hanford (Richland, Washington), and Savannah River Site (Aiken, South Carolina) cover large areas. Several DOE sites are situated in areas of complex topography and heterogeneous surface characteristics, creating mesoscale conditions that locally influence on-site weather. For these reasons, and to protect public health and safety and environment, on-site meteorological monitoring programs have been and remain an essential part of DOE atmospheric science programs.

Some DOE sites enhance the spatial resolution of the National Weather Service (NWS) observing network by taking standard surface and upper-air observations. Many of these sites are in remote areas where weather observations would otherwise be limited. Weather observations taken at a few DOE field sites are entered into the database via the NWS meteorological data distribution and display system. This distribution and display system interconnects field offices and serves as the distribution system for NWS meteorological products that are centrally produced by the National Centers for Environmental Prediction (NCEP). Other DOE sites employ Automated Field Operations and Services (AFOS) units connected to the NWS AFOS network through NOAA Air Resources Laboratory (ARL)/Special Operations and Research Division (SORD), Las Vegas, Nevada.

An accidental release of radioactive or chemically toxic material into the atmosphere can have potentially serious health effects and environmental consequences. Meteorological processes play a key role in determining the fate of radioactive or toxic chemical pollutants released into the atmosphere. Consequently, a central theme within the DOE community has been to protect public health, safety, and the environment on and around DOE facilities by measuring and characterizing atmospheric processes.

In recognition of this need, DOE has established and supported on-site meteorological monitoring programs

since 1944 (i.e., Hanford site). Each meteorological program is primarily directed towards the support of emergency response programs and in the protection of the environment and safety and health of the on-site work force and the public. In addition, research on the modeling of the transport, dispersion, deposition, and resuspension of radioactive and toxic materials is undertaken to refine the models used in these endeavors. On-site weather forecasting services tailored specifically for the special operational and emergency management requirements at each DOE site provides necessary support to the safety and health of site personnel and the public.

Much of the research and most of the operational support has been provided by the atmospheric research programs at the six major field offices directly involved in national defense programs. Over the years, these programs have grown to address many environmental, safety, and health issues. Due to the complexity of these activities, it was recognized that efforts should be made to coordinate meteorological operations and research among the field offices to enhance cost effectiveness.

The following narrative highlights meteorological activities at fourteen DOE sites:

Nevada Test Site (NTS)

The NTS is managed and operated by the DOE Nevada Operations Office (DOE/NV). The NTS has been the Nations' underground nuclear weapons testing facility and is now used to support sub-critical experiments and other national defense missions of the United States. The NTS occupies 1,350 square miles of south central Nevada and is approximately 75 miles northwest of Las Vegas, Nevada. The topography of the NTS is complex with a system of dry lake beds and mountains. Elevations range from nearly 2,700 feet (ft) above mean sea level (MSL) to 7,600 ft MSL. The climate is arid.

Meteorological services are provided to DOE/NV by components of the Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA). The DOC has had a presence on the NTS for more than 45 years through various Interagency Agreements. During this time, NOAA personnel have built a solid technical reputation in meteorological operations and emergency response. Presently, NOAA support is provided by the Air Resources Laboratory/Special Operations and Research Division (ARL/SORD), recognized for its expertise in the transport, dispersion, and deposition of radioactive and toxic materials. SORD has developed a rapid emergency response capability for the unlikely occurrence of an accidental release of radioactive or hazardous material into the atmosphere.

Both basic and applied research is carried out on problems of mutual interest to DOE and to NOAA. Emphasis is on the maintenance of meteorological support to national defense projects and to the stewardship of nuclear weapons. These capabilities focus on those facets of meteorology having a direct bearing on the transport, dispersion, deposition (i.e., fallout), and resuspension of radioactive and/or toxic materials. Other research includes documentation and study of extreme precipitation events, desert thunderstorms, cloud-to-ground lightning, and environmental issues related to air quality and visibility.

ARL/SORD provides full meteorological support to all DOE/NV operations on and off the NTS. Meteorology plays a key role in environmental, safety, and health responsibilities of DOE/NV. The SORD staff is responsible for conducting a modern program in support of nuclear and non-nuclear projects authorized by DOE/NV. Furthermore, the mission of SORD involves technical support to the emergency preparedness and response activities of DOE/NV. SORD operates a comprehensive meteorological monitoring program for the NTS, and provides meteorological and climatology services required to support the DOE/NV and contractor programs at the NTS and elsewhere, as necessary. Personnel at SORD also consult with senior scientists and engineers at the DOE National Laboratories, National Aeronautical and Space Administration (NASA), private contractors, Desert Research Institute (DRI), United States Geological Services (USGS), United States Forest Services (USFS), and other NOAA laboratories.

The SORD meteorological monitoring network consists of thirty-one (31) 10m towers and two 30m towers. Wind direction and speed is measured at the 10m level on all the towers and temperature and relative humidity is sampled at the 2m level. Data from these towers are transmitted via microwave radio to a central processor that checks the data, creates data files, and archives the data every 15 minutes. The data files are accessed by microcomputer to create graphics products for operational use and for immediate display at 15-minute intervals.

SORD also operates two 915MHz vertical profilers on the NTS--one located in the middle of Yucca Flat and one at the Hazardous Materials Spill Center (HMSC) in Frenchman Flat near Mercury, Nevada. In addition, a NOAA full surface radiation (SURFRAD) budget station is operated and maintained at the Desert Rock Meteorological Observatory (DRA) located in the southern part of the NTS. Upper-air soundings are taken twice daily, at 00 and 12 Universal Time Coordinated (UTC) from the DRA facility. SORD also operates mobile upper-air sounding systems and mobile pilot balloon (PIBAL) equipment to support special projects requiring winds aloft data in real-time.

Large-scale meteorological data and National Center for Environmental Prediction (NCEP) weather forecast products are received via AFOS and AWIPS, or from University Center for Atmospheric Research (UCAR) and ARL-Silver Spring. SORD is the DOE node for distribution of NOAA/NCEP AFOS products. Other weather products supplied to DOE contractors, the National Laboratories (e.g., SNL, LANL, and LLNL), the NWS, and Nellis AFB include real-time cloud-to-ground lightning flash graphical products and local forecast products. SORD has also recently implemented the Regional Atmospheric Modeling System (RAMS) that can predict boundary layer air flow over complex terrain. RAMS accesses the NCEP predictive model outputs and is run at the University of Nevada at Las Vegas Supercomputer Center on a daily basis.

SORD provides meteorological monitoring support and project-specific weather forecast services to the Nuclear Emergency Search Team (NEST), the Federal Radiological Monitoring and Assessment Center (FRMAC), and the Accident Response Group (ARG) activities. Monitoring support includes surface and upper-air data collection and analysis. Weather forecast service entails maintaining a constant weather watch for conditions that might impact NEST/FRMAC/ARG operations and personnel, issuing site-specific mesoscale wind, stability, and weather forecasts, aviation weather support, and providing consultation to the On-Scene Commander and to National Laboratories personnel. SORD maintains a web site (*www.sord.nv.doe.gov*) that includes graphical products that display current meteorological conditions on the NTS, including data from SORD vertical profilers and climatological data.

Idaho National Engineering and Environmental Laboratory (INEEL)

INEEL is managed by the Idaho Operations Office and is on 890 square miles of rolling, arid terrain in southeastern Idaho at the foot of the Lost River and Lemhi mountain ranges. The primary mission of the INEEL for years has been nuclear reactor research with a focus on cleanup and environmental restoration. Meteorological services and supporting research are provided to INEEL via NOAA ARL Field Research Division (FRD). The Division, under administration from various agencies, has provided support to INEEL for over 50 years. Its current mission to DOE/ID is to support emergency response and operations with real-time meteorological data, climatological data, weather predictions, dispersion calculations, and consultation. ARL/FRD maintains other capabilities that are not funded directly by DOE. ARL/FRD designs, arranges, and conducts field studies as needed to evaluate the performance of transport and dispersion models over local, regional, and continental scales, and to obtain high quality databases for model improvement. An airborne geosciences program is also maintained to measure fluxes of carbon dioxide, water vapor, and other atmospheric constituents that affect climate. These interactions provide ARL/FRD staff with additional insights that aid in the understanding of local meteorological phenomena.

ARL/FRD operates a large meteorological monitoring network to characterize the meteorology and climatology of the INEEL site. The network consists of thirty-three meteorological towers that are deployed both on-site and off-site. The overall meteorological measurement program is designed to provide representative data for the INEEL to meet specific operational and potential emergency response situations. The network covers an area of approximately 15,000 square miles. Many of the towers are 15 meters (m) tall and provide wind speed and direction at 15m and air temperature at 2 and 15m. Fifteen of the 15m towers also provide relative humidity at 2m, precipitation, and global solar radiation, eleven provide barometric pressure. The other three towers range from 46 to 76m in height and are instrumented at multiple levels. The sensors at all stations are scanned every second and averaged or totaled over five minutes.

The data are subsequently retrieved into the data display and archive system at the ARL/FRD office through a radio repeater located at an elevation of 8,930 ft MSL. Continuous wind and temperature profiles are obtained from a 915MHz radar wind profiler and Radio Acoustic Sounding System (RASS). A Doppler SODAR supplements the wind profile at lower levels with higher resolution data. Meteorological data are quality-controlled through automated and manual processes.

INEEL meteorological monitoring and emergency response efforts are enhanced with the use of an ARL/FRD meteorological data display and visualization program known as INEELViz. This program has been widely deployed at 50 sites on and around the INEEL for access by federal, state, and Indian tribes via the Internet. Within INEELViz, meteorological data are displayed in real-time and overlaid on maps of the local area that include political and terrain features. In addition, the local MDIFF puff dispersion model can be accessed through the INEELViz front-end and the model output can be displayed as trajectories or concentration isopleths on the INEELViz display screen. The incorporation of RSAC dose conversions permits the user to also view real-time dose estimates from the model output. These features have become very useful enhancements to the INEEL emergency response capability.

Partnerships forged with DOE-ID, the State of Idaho INEEL Oversight Program, and the Shoshone-Bannock Indian Tribes have resulted in addi-

tional methods of meteorological data dissemination. Meteorological and background nuclear radiation data from four public access sites on and surrounding the INEEL are displayed at nearby kiosks in real-time. Additional information on nuclear radiation and meteorological tutorials are presented at the kiosks. The data are also available on the Internet at *http://oversite.inel.gov*. ARL/FRD maintains its own web site at *www.noaa.inel.gov*.

Lawrence Livermore National Laboratory (LLNL)

The Lawrence Livermore National Laboratory (LLNL) is located in a valley in California's Coast Range Mountains about 25 miles east of Oakland. LLNL covers approximately 2 square miles and is operated by the University of California for the DOE Oakland Operations Office. Two groups are involved in the atmospheric sciences at LLNL: the Environmental Protection Department (EPD) and the Atmospheric Sciences Division (ASD).

EPD operates a 40m tower and supplies meteorological data for facility operations, regulatory compliance, and emergency response. Real-time and historical data are available via the World Wide Web (*http://www-metdat.llnl.gov/*).

Within the LLNL Earth and Environmental Sciences Directorate, ASD conducts research on climate and weather processes on local to global scales on the following issues:

(1) Understanding the transport, diffusion, deposition, transformation, and atmospheric effects of accidental releases or pollutants;

(2) Developing and testing models for improved representation of atmospheric processes on building, urban, regional, and global scales;

(3) Understanding the uptake and removal of carbon dioxide emitted through fossil fuel combustion by the biosphere and oceans so that the effects of future emissions may be accurately predicted;

(4) Understanding the role of pollutants from fossil fuel emissions in determining greenhouse gas and aerosol concentrations and climate forcing;

(5) Understanding and predicting the extent to which stratospheric ozone may decrease as a result of anthropogenic emissions;

(6) Understanding and quantifying the natural variability of the climate system; and,

(7) Understanding and quantifying interactions between the biosphere and climate. Some of these efforts stem from the need to be able to predict the regional to global environment and its changing nature over the next few decades, so that policy makers will have the information needed for the formulation of national energy policy.

LLNL ASD scientists contribute to two long-term DOE research programs--ARM and the Chemical Biological Non-proliferation Program (CBNP) as well as lead two other programs--PCMDI and ARAC. The Program for Climate Model Diagnosis and Inter-comparison (PCMDI) develops and distributes software tools to facilitate model diagnosis and inter-comparison, documents the features of models that are in use by the world climate community, and archives extensive collections of model output data. The Program also provides quality global observational products for application as model validation data (*http://www-pcmdi.llnl.gov/*).

Since 1979, LLNL has provided emergency response services via the Atmospheric Release Advisory Capability (ARAC) program. ARAC is a centralized federal resource responsible to DOE, the Department of Defense (DOD), and other federal agencies under the auspices of the Federal Radiological Emergency Response Plan (FRERP). The ARAC mission is to deliver realistic real-time graphical dose and exposure assessments to emergency decision-makers to assist in the protection of populations at risk for releases of radiological and other hazardous material to the atmosphere. ARAC supports all elements of the DOE Emergency Preparedness and Response Program, NEST, ARG, FRMAC, and the Radiological Assistance Program (RAP).

ARAC maintains and operates the National Atmospheric Release Advisory Center (NARAC). NARAC consists of automated continuous worldwide meteorological data acquisition, detailed worldwide terrain and geographic mapping databases, and a suite of three-dimensional, complex terrain, atmospheric dispersion models prepared to assess explosions, fires, vents, spills, or other releases of radiological or hazardous material. ARAC has an entirely new emergency response system with state-of-the-art, high-resolution, terrain-following, variable-gridded diagnostic meteorological and dispersion models including new user interfaces and extensive graphical displays. In addition, the system includes relocatable prognostic model that provides high-resolution 2-3 day forecasts in the region of interest.

NARAC provides a 24-hour on-call response, using redundant computer systems with uninterruptible power. NARAC provides on-site and off-site emergency response services to about 40 DOE and DOD facilities around the United States via a Site Workstation System linked to Livermore. Each Site Workstation also collects on-site meteorological data from one or more towers. The response time for the delivery of an initial ARAC assessment is less than 15 minutes for a computer-linked site and 45-90 minutes for a non-computer-linked site. ARAC has responded to over 80 real-world events and conducted thousands

of exercises with supported sites and agencies.

More information on the ARAC program can be located on the Internet (*http://www-ep.es.llnl.gov/www-ep/atm/ARAC/arac.html*) and an educational presentation of some past ARAC responses is located at *http://air.llnl.gov/*.

Oak Ridge Reservation (ORR)

The ORR is home to four DOE sites: Oak Ridge National Laboratory (ORNL), the Y-12 Plant, the East Tennessee Technology Park (ETTP, formerly K-25 Site), and the Oak Ridge Institute for Science and Education (ORISE). Managed by the Oak Ridge Operations Office (ORO), the ORR encompasses nearly 100 square miles of hilly and heavily vegetated terrain in eastern Tennessee.

Meteorological network systems which support day-to-day operations are managed and operated at the three main sites by Lockheed Martin Energy Systems, Lockheed Martin Energy Research and Bechtel Jacobs Company. These network systems provide data that support environmental management (permitting, facility siting and environmental impact assessment), facility safety (safety analyses), emergency management (hazards and consequence assessment), operations (work planning) and substantial research.

The meteorological data acquisition program at ETTP has two main towers. K-1209 is 60m high while K-1208 is 30m in height. In addition, two 10m battery-powered supplemental towers are still operating. A SODAR system, near the K-1209 tower also remains operational. Lastly, real-time output from an automatic lightning detection system that captures strike data from as far away as 100 nautical miles, a NEXRAD radar system, and *The Weather Channel* are available to each of the control rooms and emergency response facilities.

The Y-12 Plant has two meteorological towers (60m and 100m) located at the east and west ends of the site. ETTP and Y-12 Plant meteorological data is fed into the ORR Emergency Operations Center (EOC) and at emergency control centers for hazard assessment, consequence assessment, and protective action recommendations.

The data acquisition program at the ORNL consists of three (two 30m and one 100m) meteorological towers. Meteorological data is fed to an ORNL central computer system for analysis and dissemination.

The NOAA Air Resources Laboratory/Atmospheric Turbulence and Diffusion Division (ARL/ATDD) is located in Oak Ridge near the ORR. The primary mission of ATDD is atmospheric research. Substantial research programs at ATDD are undertaken with the assistance of staff from ORISE/Oak Ridge Associated Universities (ORAU) and scientists from other national laboratories and organizations in the United States and abroad. ARL/ATDD also works closely with the ORAU to enhance educational opportunities in atmospheric science.

ARL/ATDD research attention is focused on the physics of the lower atmosphere, with special emphasis on the processes contributing to atmospheric transport, dispersion, and air-surface exchange, and on the development and improvement of predictive capabilities using the results of this research. Many other projects are underway such as surface energy balance and CO_2 exchange studies and long-term studies of CO_2 exchange aimed at process-level understanding. Operationally, ARL/ATDD personnel provide meteorological consultation and supplemental data for air quality analyses, environmental reports, and hazard and consequence assessments. Local climatology data are routinely collected and distributed. Under NOAA funding, ARL/ATDD operates a regional network of 15 towers ranging from the Cumberland Mountains (middle Tennessee) to the Smoky Mountains on Tennessee's eastern border. Wind, temperature, and precipitation data are recovered every 15 minutes by telemetry and made available to users.

ARL/ATDD incorporates NWS forecast products into the high-resolution, regional, meteorological model (i.e., RAMS) to produce twice-daily 12-hour, 24-hour, and 36-hour predictions of surface winds for eastern Tennessee, and transport trajectory predictions for the ORR.

Sandia National Laboratory (SNL)

The DOE Kirtland Area Office manages SNL in Albuquerque, New Mexico, located between the Rio Grande Valley and Manzano Mountains. SNL covers approximately 80 square miles of flat to mountainous arid terrain. Meteorological Programs at SNL include both support and research activities.

Meteorological services and support are provided through the Environmental Operations Center (EOC) in the Laboratory Services Division (LSD). The mission is to provide meteorological support for various operations including: (1) emergency response, (2) environmental surveillance and characterization; and (3) regulatory compliance.

The monitoring network consists of six 10m and two 60m towers used to measure wind direction and speed, ambient temperature, and relative humidity. There are also three precipitation gauges, two barometric pressure sensors, and one solar radiation pyranometer in the network.

Key research activities are provided through the Energy and Critical Infrastructure Center in the Energy, Information, and Technology Division. SNL/NM scientists are involved in the Atmospheric Radiation Measurement (ARM) program and the Surface Heat Budget of

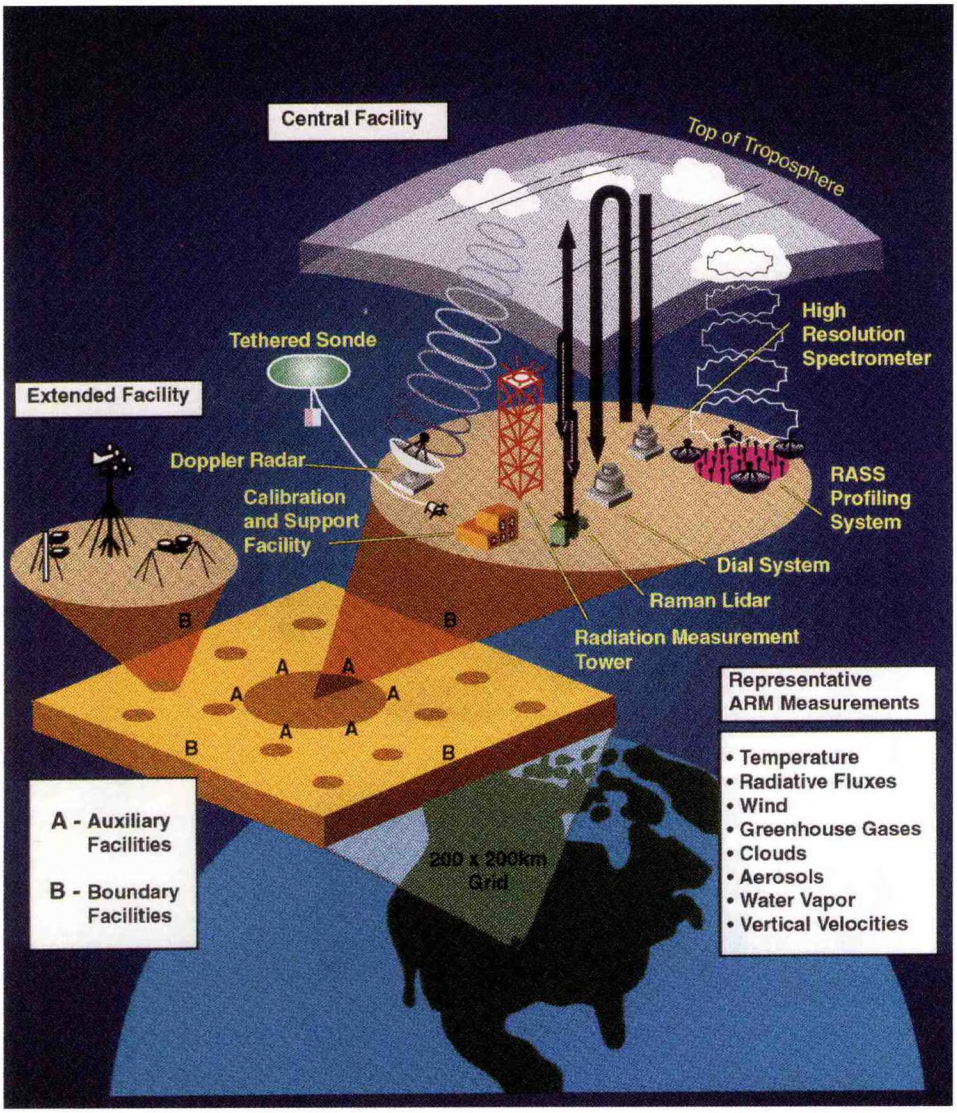


Figure 3-DOE-1. Program overview of DOE's Atmospheric Radiation Measurement (ARM) Program.

the Arctic Ocean (SHEBA). The ARM project is a combined measurement and modeling program (Figure 3-DOE-1). The goal is to gain a better understanding of clouds and their effect on atmospheric radiation, with the final goal of developing better climate models. The SHEBA program addresses the interaction of the surface energy balance, atmospheric radiation and clouds over the Arctic Ocean.

Los Alamos National Laboratory (LANL)

LANL is operated by the University of California under the responsibility of the Albuquerque Operations Office, and is spread across 43 square miles (112 km^2) of the Pajarito Plateau at the foot of the Jemez Mountains that extend up to around 900m above the plateau. LANL is about 30 miles northwest of Santa Fe in north central New Mexico. The Pajarito Plateau slopes to the east-southeast, dropping 400m across the Laboratory, with canyons and mesas running along the slope of the plateau. The broad Rio Grande Valley lies to the east of the laboratory. Los Alamos has a semi-arid, temperate, mountain climate.

The operational meteorological program at Los Alamos operates a network of six towers (ranging in height from 23m to 92m), a mono-static Doppler SODAR, and three supplemental precipitation stations. Data from four instrumented meteorological towers that are located on the Pajarito plateau drives a diagnostic wind field for the program's plume modeling capability. A fifth tower is located in Los Alamos Canyon to give information on the larger canyons in the area, and a sixth tower is located on top of Pajarito Mountain to measure ambient conditions. The SODAR gives information on winds up to the level of the Pajarito Mountain tower.

More than 100 instruments, consisting of over 20 different types of sensors, are used to collect data throughout the network. Variables measured by the program can be grouped into the categories of wind, SODAR-derived wind, atmospheric state, precipitation-related, radiative fluxes, eddy heat fluxes, subsurface measurements, and fuel moisture. Data collected by the network are checked for quality before its archival, and raw data and real-time displays of graphs and tables are made available via the Internet.

The LANL Air Quality Group provides regulatory and environmental surveillance leadership and services to meet LANL air quality obligations and public assurance needs. The group develops and implements programs to ensure and address institutional compliance with State and Federal laws related to air quality regulations, DOE orders for emergency management, air quality surveillance, dose assessment activities, and community concerns related to air quality issues. The group takes a proactive approach to managing air emissions by providing continuous air monitoring and measurement of external penetrating radiation on-site and off-site. The group also coordinates LANL activities to ensure full compliance with air emission regulations, providing monitoring and modeling for emergency response, and assisting operating groups in developing and implementing new methods and systems to reduce emissions to as low as reasonably achievable. The

monitoring capabilities of the Air Quality Group are supplemented by the field team of the Atmospheric and Climate Sciences Group, that operates various sensor systems including a unique Raman lidar system to obtain images of atmospheric water vapor distributions.

Research within the LANL Atmospheric and Climate Sciences Group supports DOE missions in both the defense and civilian sectors, such as work in the propagation of very-low-frequency sound ("infra-sound") waves. Modeling studies contributed to understanding of propagation and, in particular, sources of infrasound. Just as it is possible to infer earthquake epicenters from seismic wave observations, infra-sound sources can be inferred from atmospheric observations. This work is an important component of monitoring compliance with the proposed Comprehensive Test Ban Treaty (CTBT). The CTBT work involves a number of organizations within DOE and DOD community, including interactions with other DOE laboratories within the CTBT Research and Development program.

Operational issues involve close work with the Air Force Technical Applications Center (AFTAC) at Patrick AFB, Florida, the DOD organization that handles monitoring systems. In addition, several active international collaborations with other infra-sound researchers are ongoing.

The Meteorology Team within the Atmospheric and Climate Sciences Group at Los Alamos National Laboratory conducts analysis and modeling on microscale to mesoscale atmospheric flows and phenomena. In support of the DOE Chemical and Biological Non-proliferation Program, a model for High Resolution and Strong Gradient (HIGRAD) applications is being used to study the effects of radiative heating and shading around groups of buildings. The objective of this study is to determine how these processes may influence the transport of agents within the urban environment. On larger scales, the team is examining the influence of flow merger and urban roughness on the vertical transport and mixing of pollutants with the Regional Atmospheric Modeling System (RAMS) for several western United States valleys and basins. This project is in support of the DOE Environmental Meteorology Program and for the Environmental Protection Agency (EPA). As part of the LANL initiative in Coupled Environmental Modeling, researchers within the Meteorology Team are developing a physics-based fire behavior model (FIRETEC) and coupling this model to the HIGRAD atmospheric dynamics code to examine the details of the interaction between local winds and the intense heat generated by wildfires. Also as part of this initiative, a land surface model is being coupled that includes hydrologic processes (i.e., SPLASH) to the RAMS mesoscale model for multi-seasonal simulations of the water resources of the upper Rio Grande Basin.

Meteorology Team members are also working on the LANL Urban Security project, which is linking physical and urban growth models to address the needs of cities. In this framework, we are using the RAMS model to provide meteorological fields for use by air chemistry, urban runoff, and other models. The Meteorology Team within the Atmospheric and Climate Sciences Group conducts analysis and modeling on microscale to mesoscale.

On global scales, research within the LANL meteorological community involves the study of climate change and variability. A major project is the development of a global coupled ocean-atmosphere model sponsored by the DOE Climate Change Prediction Program. The global model being developed consists of a Los Alamos global ocean Global Climate Models (GCMs) Parallel Ocean Program (POP), the Los Alamos sea-ice model (CICE), the NCAR Community Climate Model (CCM3), and a "flux coupler" to link the media consistently. The two GCM's and the CICE model exchange heat, momentum, and water mass across the air-sea boundary. A ten-year synchronized simulation revealed the synoptic weather events, seasonal cycles and inter-annual variations.

Observations related to understanding global climate are the focus of the Tropical Western Pacific (TWP) Program Office LANL, an element of the DOE ARM Program. The TWP Program Office is responsible for the development and operation of the TWP CART locale, a large expanse of tropical ocean and maritime continent lying roughly between 10° S and 10° N latitude and from 135° E to 150° W longitude. The maritime continent area is largely in the southwest and the open ocean area in the northeast of the locale. The local climate is characterized by warm sea surface temperatures, deep and frequent atmospheric convection, high rain rates, strong coupling between the atmosphere and ocean, and substantial variability associated with El Niño Southern Oscillation (ENSO) phenomenon.

Scientific questions that need to be addressed in the TWP can be grouped under three main headings: (1) radiation budget and cloud forcing, (2) water and energy budgets; and (3) ocean-atmosphere interactions.

The program supports a variety of operations at LANL. The primary client of the program is the Emergency Management Group, for which the program provides a plume modeling capability. Other clients use the program's data for such activities as operations and planning, hazard and accident analyses, environmental studies, support for experiments, compliance, and documentation.

Pantex Plant

The Pantex Plant covers 15,977 acres and is located 27 kilometers (17 miles) northeast of Amarillo, Texas, in Carson County. The Plant was a World War II munitions factory and was converted to a nuclear weapons assembly facility in 1951. Today, it is the nation's only assembly/disassembly facility supporting the nuclear weapons arsenal. Pantex Plant is a government-owned, contractor-operated facility. DOE oversees operation of Pantex Plant through the Amarillo Area Office, which reports to the Albuquerque Operations Office. Mason and Hanger Corporation have been the operating contractor since 1956.

The Waste and Environmental Management Department (WEMD) of the Applied Technology Division is tasked with the quality assurance program for the meteorological data captured by the one on-site two-level tower located in the northeast corner of the Plant site. The data from this tower (10m and 60m) are collected and used by the DOE ARAC site work station, located in the Plant EOC. These data are collected and archived as 15-minute averages plus maximum and minimum values for each 15-minute period. They are primarily used for input to the ARAC emergency response models that could be used for off-normal events involving radionuclides. Annual dispersion model calculations, of off site radiation doses from on site sources, required by 40 CFR 61, Subpart H, *National Emission Standards for Hazardous Air Pollutants* (NESHAP), are accomplished by WEMD using the EPA approved CAP88PC model and the Pantex meteorological tower data processed into the STAR format. WEMD also maintains the Pantex Plant climatology database.

Meteorological tower data is also used by the Risk Management Department for plume dispersion modeling applied to the Plutonium Dispersal Consequence Analysis for the Basis for Interim Operations (BIO) validation and upgrade reports, other operations directives, and other safety analyses.

Routine preventive maintenance on the meteorological instruments as well as calibration and certification are done semi-annually by the United States Bureau of Land Management (BLM). The BLM maintenance depot at Boise, Idaho performs similar work for the United States Forest Service's own meteorological towers instruments. This work is done under a contract administered by Battelle-Pantex. Emergency repairs and replacement of sensors are also handled by the BLM Idaho depot. Temperature and wind sensors are replaced semi-annually with calibrated and certified sensors. The barometer is replaced annually. During the semi-annual preventive maintenance visits, all of the other instruments are replaced by the BLM technician with rebuilt/refurbished, calibrated equipment, from the Idaho depot. The maintenance check also includes the telephone line, modem, and backup power supply.

No special meteorological activities are planned at Pantex for FY 2000; however, efforts are underway to display the meteorological tower data on the Pantex Plant Intranet for use by Plant personnel. There are no current or projected supporting meteorological research activities planned at Pantex.

Savannah River Site (SRS)

The SRS is under the responsibility of the Savannah River Operations Office (SR) and operated by the Westinghouse Savannah River Company. SRS is located in southwestern South Carolina, along the banks of the Savannah River. The SRS covers an area of approximately 300 square miles. It is heavily vegetated with evergreen trees and contains many streams, a swamp, and a 2,700-acre reservoir built as a cooling pond for the plant reactors. The topography of SRS is characterized by gently rolling forested hills with an adjacent flood plain near the Savannah River. The climate at SRS is typical of the southeastern United States with long, hot and humid summers and short mild winters.

The Atmospheric Technologies Group (ATG) of the Savannah River Technology Center (SRTC) developed the SRS meteorological monitoring and modeling program in the early 1970's. This program supports the SRS operations in the areas of emergency response consequence assessment, radiological and non-radiological air quality calculations for regulatory compliance, safety analyses, environmental impacts, engineering studies, environmental research and non-proliferation activities.

Meteorological activities include daily weather forecasting services in support of operations at SRS, with particular emphasis on severe weather impacts. Local meteorological data are obtained from a network of eight 200-foot meteorological observing towers located near the major production sites. The instrumentation on these towers includes sensitive bi-directional vanes (i.e., bi-vanes), cup anemometers, resistance thermometers and lithium chloride humidity sensors. Additional meteorological instrumentation is located at the Central Climatology Facility located near the geographical center of the site to measure precipitation, evaporation, barometric pressure, soil temperature, solar and long wave radiation. Central Climatology includes a 200-foot tower instrumented at four levels. A network of twelve additional rain gauges (that are read daily) is located within SRS. Additional local upper-air data are collected from three acoustic Doppler radars, an airsonde system, and a tethersonde system. Portable towers are used for case studies.

A collaborative agreement with surrounding counties involves assisting them to install and operate several local meteorological towers at nearby

chemical plants. Data from these towers are being integrated into the SRS meteorological archiving and display system the Weather Information and Display System (WINDS).

The WINDS is the primary consequence assessment system for atmospheric and hydrologic releases from SRS operations. A suite of atmospheric models linked to real-time site wide atmospheric monitoring provides transport, dispersion and consequence calculations for emergency response.

The WIND system underwent a complete re-engineering to improve the computer system reliability, performance and serviceability. The re-engineering involved distributing the data processing and utilizing new data acquisition hardware and relational data base software. New workstation clustering for data management and PC/NT user workstations for local model operation and graphical user interfacing for displays were added.

An advanced non-hydrostatic, three-dimensional, prognostic atmospheric model is run twice daily on the SRTC's CRAY computer separate domains: (1) the Central Savannah River Area (CSRA), (2) kilometer grid resolution); and (3) the area encompassing South Carolina and Georgia (20 kilometer resolution).

The CSRA model provides forecasts with a minimum of six hours useable forecast fields. The Georgia-South Carolina model run provides forecasts with a minimum of 24 hours useable forecast fields. These forecast fields are integrated into the WIND system consequence assessment models. Additional model runs are conducted on an expanded domain to include the entire southeastern United States on an *ad hoc* basis when the SRS is threatened by hurricanes.

An aqueous model is also resident on WINDS and linked to real-time stream flow monitors operated by the USGS. This model enables consequence assessments for emergency response to site streams and the Savannah River.

Regional, national, and international meteorological data are received from a commercial weather data provider via satellite in real-time. Weather workstations provide surface and upper observations, analyzed and forecast weather parameter fields from the NWS and the European Modeling Center. These data are input into an advanced, three dimensional, prognostic, atmospheric modeling system for applications locally in the southeastern United States and globally. Satellite and Doppler radar data are also available in near real-time.

Rocky Flats Environmental Technology Site (RFETS)

The RFETS is managed by the Rocky Flats Operations Office and is located approximately 16 miles northwest of downtown Denver, Colorado. One of the smaller DOE sites, the facility occupies a 10 square mile area along the foothills of the Rocky Mountain Front Range.

A 61m meteorological tower at the west-end of the site continuously monitors meteorological conditions at surface, 10, 25, and 60m above ground level. A backup, 10m tower is located nearby to ensure 100 percent data recovery. The data are analyzed, quality assured, and assembled into data sets for use in atmospheric modeling, climatology, and other analyses at the site. Data from the 61 and 10m towers are also transmitted back to the main site every 15 minutes by telemetry for use in emergency response modeling. The Regional Atmospheric Response Center (RARC) conducts meteorological activities associated with emergency preparedness and response at the site. An upper air remote sensing Sound Detection and Ranging/Radio Acoustic Sounding System (SODAR/RASS) continuously monitors winds, temperatures, and atmospheric stability above RFETS.

Through a cooperative agreement with the Colorado Department of Public Health and Environment, meteorological data are transmitted to the site from five surface meteorological stations by telemetry that form a ring around the site perimeter. Another cooperative agreement with NOAA provides near real-time data from multiple monitoring sites throughout the Denver metropolitan area. These data are all received, quality assured, and combined into a 3-dimensional observation set for emergency response modeling every 15 minutes, 24 hours per day.

The RARC provides 24-hour consequence assessment support for any unplanned radiological or chemical releases from the site. The Center responds with customized weather forecasts, plume projections, and dose modeling results that lead to event classifications and protective actions for on-site and off-site populations. RARC also conducts specialized consequence assessments in support of emergency preparedness, hazard assessments, and risk assessments for RFETS. Weather forecasts are provided for severe weather events, such as winter storms, windstorms, and severe thunderstorms.

A customized modeling system has been developed and implemented at RFETS to predict the path and impacts from any radiological emergency at the site. Called the Computer-Assisted Protective Action Recommendation System (CAPARS), the new capability addresses the need for fast, accurate plume predictions in a complex atmosphere.

CAPARS provides a variety of plume, weather, hazard, and related products with the accuracy and speed needed for response to an emergency at RFETS. Eleven integrated major subsystems form the overall CAPARS capability. The State of Colorado has formally accepted the CAPARS modeling system for emergency response and planning applications at RFETS. A specialized planning version of the

CAPARS system has been developed, implemented, and applied for emergency planning at the RFETS. Called the TRAC Risk Assessment/Hazards Assessment Model, the capability is designed to support hazards and risk assessments for RFETS and to form the basis for an evaluation of the size and shape of the Emergency Planning Zone (EPZ) surrounding RFETS.

Hanford Site

For more than 55 years, meteorological services have been provided to the Richland Operations Office and the Hanford Site. For the last 33 years, this program has been managed by the Battelle Pacific Northwest National Laboratory) (PNNL). Not only has operational support been provided, but also supporting research into atmospheric processes has been a key part of the PNNL support to DOE Richland. The facility covers 560 square miles within the arid and sparsely vegetated Columbia River basin in southeastern Washington.

Global Climate Research Program focuses on the study of basic geophysical processes and on the development of databases that are critical for understanding global and regional climate change. The ARM program is designed to characterize empirically the radiative processes in the atmosphere with high spatial, temporal, and spectral resolution and accuracy at three climatically distinct sites--the Southern Great Plains of Oklahoma; the tropical Western Pacific just off the northern part of Papua, New Guinea; and the north slope of Barrows, Alaska. In addition, carbon dioxide emissions research is aimed at providing a scientific basis for forecasting future emissions of carbon dioxide and other important gases of radiative importance.

The PNNL Meteorological and Climatological Services Project (MSCP) office provides meteorological monitoring and operational support. The monitoring system consists of an array of twenty-six 10m towers, three 60m towers and one 125m tower instrumented with temperature and wind direction and speed sensors. Atmospheric pressure and precipitation data are also collected. Data from this network are transmitted via UHF radio to a computer that decodes the data and plots graphics products for immediate display and use by Hanford Meteorological Station personnel. Other meteorological data are received via the NWS/DOE AFOS network. Meteorological services include emergency response functions, weather forecasting for on-site operations and special projects, and climatological support. MSCP support to the Hanford site includes: (1) extensive data acquisition via a site-wide meteorological monitoring network; (2) weather forecasting services 24-hours/day (Monday through Friday), and 8-hours/day on weekends and holidays; (3) hourly surface observations, and 6-hourly synoptic observations; and, (4) monthly and annual climatological data summaries, plus meteorological input to annual environmental reports.

Brookhaven National Laboratory (BNL)

The BNL, under the responsibility of the Brookhaven Area Office, has been active in both operational meteorology and atmospheric sciences for the past 50 years. BNL is now managed by the Brookhaven Science Associates which is a joint venture by Battelle Memorial Institute Incorporated, The Research Foundation of the State University of New York at Stony Brook, and six other core university partners. Meteorological operations and research cover a wide range of programs encompassing interpretive and theoretical studies. BNL is located near the geographical center of Long Island, New York. Long Island is glacial in origin and, as a result, has sandy soil, mostly gentle undulating contours, and a single water aquifer for the entire island. Elevations vary between 20m and 35m. The BNL site is rectangular and approximately 5,200 acres in area. Winds are predominantly southwesterly, and plume dispersion studies show that it is essential to monitor winds well beyond laboratory borders. The NWS New York City Weather Forecast Office is located at BNL. This office has an umbrella of coverage that includes an estimated population of 1 million. Nearby, in Bohemia, is the NWS Eastern Regional Headquarters that administers a 12-state region.

The mesoscale meteorological measurements necessary for emergency response are the responsibility of the Meteorological Services Group, a support group under the Department of Applied Science, Environmental Biology and Instrumentation Division (EBID).

The Meteorological Services Group maintains two meteorological towers, 10m and 88m, and an instrument shelter. By integrating redundant pairs of standard, approved meteorological sensors throughout the system, an overall data availability of better than 99 percent is achieved. The real-time data are merged into the laboratory emergency response network. A database of 50 years (in digital format since 1960), one of the longest continuous meteorological time series in the United States, is archived and is available. A real-time monitoring network with worldwide web access covers the east-end of Long Island. Coastal weather stations at Smith Point and Orient Point transmit data each minute. Pollution-monitoring data buoys are added during field programs.

The Meteorological Services Group provides a locally tuned forecast twice daily during normal working hours. Weather forecasts and data are available by telephone or the Internet (*www.weather.bnl.gov*). During severe weather events updates are given every 3 hours and, in the case of a hazardous material or radiological

Figure 3-DOE-2. Battelle operates the Gulfstream-1 as a research facility under contract with the DOE's Atmospheric Chemistry Program.

release, a member of the Meteorological Services Group will assist the emergency coordinator with regular forecasts and information on local wind fields and gustiness. Areas of meteorological research include:

(1) instrumentation development for field studies of atmospheric constituents, air-sea interaction, and laboratory experiments;
(2) gaseous tracer studies of atmospheric transport and dispersion;
(3) aerosol formation and behavior;
(4) atmospheric pollution studies;
(5) modeling of atmospheric chemical reactions;
(6) acid rain studies both in the field and in the laboratory;
(7) theoretical and observational studies of radiative transfer and fluxes; and,
(8) analysis of data and development of parameterizations relevant to global climate change.

The Atmospheric Radiation Measurement (ARM) Program provides the stimulus for a wide range of climate-related studies. The ARM ocean monitoring program is developing instrumentation and a broad ship- and buoy-based observational network in the tropical western Pacific Ocean. The Atmospheric Chemistry Program (ACP) provides the Atmospheric Chemistry Division's concern with aerosol sources, transport, and fate in the global atmosphere and the overall, and little understood, impact of aerosols on global climate dynamics. The ARM External Data Center is the center for collection, archival, and dissemination of all climate-related data sets for the ARM program (Figure 3-DOE-2)

An exciting new effort in radar meteorology focuses on algorithms for cloud detection and cloud mapping using both the WSR-88D radar network and research radar. BNL is a site in the NASA Solar Irradiance Network and continuous short wave absorption measurements are made here. In a related NASA study, oceanic aerosol optical depths are measured and used to validate absorption algorithms in the SeaWiFS ocean color program.

The Optical Remote Sensing group within the Department of Advanced Technology is presently modifying one of its Raman lidar systems for vertical profiling of carbon dioxide. The Raman lidar instrument is a self-calibrating sensor that means that data from a variety of locations in the world can be compared. With the incorporation of a large (1.25m) antenna and advanced filters and detectors, a vertical profile of CO_2 concentration with a precision of 1 part per million (ppm) (Note: atmospheric mean = 370 ppm) and maximum height of 2-3km can be produced routinely. These profiles will support model development and validation. Importantly, comparison of CO_2 concentrations collected throughout the world and over time will prove invaluable in confirming adherence to the Kyoto protocols.

Waste Isolation Pilot Plant (WIPP)

The Waste Isolation Pilot Plant (WIPP) is operated by Westinghouse Electric Company's Waste Isolation Division for the DOE Carlsbad Area Office. A cornerstone of the DOE's national clean-up strategy, the WIPP is designed to permanently dispose of transuranic radioactive waste generated by defense-related activities in the Salado salt formation 2,150 ft beneath the surface. WIPP is located in Eddy County in southeastern New Mexico, 26 miles east of Carlsbad, and occupies 16 square miles of a region know as Los Medanos. Geographically, the region is regarded as a relatively flat, sparsely inhabited plateau with little surface water.

The WIPP Environmental Monitoring (EM) Section performs meteorological monitoring as part of the Non-radiological Environmental Monitoring Program. The primary meteorological station provides measurement of wind direction and speed, temperature at 2, 10, and 50m, as well as ground level measurements of barometric pressure, relative humidity, precipitation, and solar radiation. The main function of the station is to generate data for operational support, emergency response and regulatory dispersion modeling applications. Parameters are monitored continuously and the data are stored in the Central Monitoring System, a computerized system including automated parameter checks, real-time displays in the Central Monitoring Room, and data archiving. Meteorological data are compiled and distributed to stakeholders, including the NOAA NWS, on a monthly basis.

In addition to the primary meteorological station, the Far Field Station serves as a secondary meteorological station and measures wind direction and speed at 10 meters as well as temperature, barometric pressure at ground level. System upgrades are currently being considered for this station.

WIPP also, under a cooperative agreement with the NWS, maintains a Cooperative Weather Observing Station at the Far Field Station. Data from this station are compiled monthly and the Record of Climatological Observations form is submitted to the Weather Forecast Office in Midland, Texas. Under the same cooperative agreement, the Midland office is given

access to real-time data from the primary meteorological station.

Weldon Springs Site Remedial Action Project (WSSRAP)

Various facilities at Weldon Springs in St. Charles County, Missouri were no longer needed, and a Remedial Action Plan (RAP) was developed to restore the site to its environmental baseline. This activity is being coordinated under the Weldon Springs Site Remedial Action Plan (WSSRAP), under the management of Jacobs Engineering Company.

Fourteen interim response actions were developed and approved by WSSRAP. Interim response actions are activities that will not change the ultimate disposal method but will mitigate or eliminate conditions that pose immediate or potential threats to worker safety, public health, or the environment. Some of the interim actions taken were removal of exposed friable asbestos, overhead piping, polychlorinated biphenyl (PCB) electrical equipment, power poles and wires, demolition of all buildings, isolation and capping of Ash Pond, and capping of other highly contaminated areas. Additional areas to undergo remediation are scheduled through 2001, which is the projected date for completion of all remediation activities.

Within the Environmental Monitoring Plan is a meteorological monitoring program, which has a monitoring station. The meteorological monitoring station is located along the eastern perimeter of the chemical plant site more than 400 ft from the nearest building and is considered representative of all areas undergoing remediation. The WSSRAP meteorological station continuously records wind speed and wind direction at 10m above ground level, as well as horizontal wind fluctuation, barometric pressure, relative humidity, incoming solar radiation, and precipitation intensity. The sensors are designed for and calibrated within measurement ranges encompassing all credible meteorological conditions at the site.

The meteorological monitoring program include numerous program functions at WSSRAP:

(1) Meteorological information to support emergency response activities in the event of an unscheduled chemical or radiological release;

(2) Information for atmospheric dispersion modeling to provide an environmental safety and health contribution to engineering design of site facilities;

(3) Rainfall, temperature, and wind speed data to support wetland and lake ecological studies and for support of foliar vegetation absorption analysis;

(4) Precipitation data to support the correlation of aquifer level fluctuations in the quarry and Femme Osage Slough;

(5) Environmental reporting including the annual Weldon Spring Site Environmental Report and the Effluent Information System/On-Site Discharge Information System Report;

(6) Wind speed data needed for compliance with Occupational Safety and Health Administration (OSHA) construction management activities;

(7) Precipitation data to support the National Pollutant Discharge Elimination System storm water permit application; and,

(8) Temperature and relative humidity data to support environmental safety and health field activities during periods of extreme heat and cold.

Yucca Mountain Project Office (YMPO)

An extensive air quality and meteorology monitoring program has been established at YMPO that is managed and operated by Science Applications International Corporation (SAIC), Summerlin, Nevada.

This program supports the site characterization and licensing of the site that DOE Office of Civilian Waste of Radioactive Materials has preliminarily selected for the disposal of high-level radioactive waste.

DOE Meteorological Coordinating Council (DMCC)

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

Council oversight is provided by a steering committee consisting of DOE headquarters and field element representatives. Products of the DMCC include analysis of meteorological requirements embedded in DOE orders and guidance, site meteorological program peer reviews, and, as needed, customized technical assistance. Assist visits have been conducted at DOE/NV, WIPP, Pantex, and DOE/OR. A follow-up assist visit was also conducted at WIPP. Additional assist visits are in the planning stages and will be conducted over the next several years. The DMCC web page has been broadened and can be accessed at *www.sord.nv.doe.gov*.

Planned DMCC products include a DOE meteorological human resources directory, an updated meteorological requirement analysis, site meteorological program assist visit reports, and additional upgrades to the DMCC web page.

DEPARTMENT OF THE INTERIOR WEATHER PROGRAMS

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

Bureau of Land Management

The Bureau of Land Management (BLM) is one of five Federal Land Management agencies which have centralized wildland fire weather operations at the National Interagency Fire Center (NIFC), Boise, Idaho (Figure 3-DOI-1). BLM's Initial Attack Management System (IAMS) was designed in the mid-1980's to provide real-time data access and modeling for the fire management organization. The IAMS required a considerable dedicated telecommunications network for data distribution. In an effort to reduce these inherent telecommunications costs, the BLM has moved into a "web server" environment. This new system is called the BLM Wildland Fire Management Information Site (WFMIS) (*www.nifc.blm.gov*). Many of the capabilities that were centrally located in the old IAMS have been moved to other web sites.

The principal inputs to WFMIS are Remote Automatic Weather Station (RAWS) and National Lightning Detection Network (NLDN) information. Additional fire management information is summarized and made available via the Western Regional Climate Center (WRCC) (*www.wrcc.sage.dri.edu*) and the United States Forest Service Wildland Fire Assessment System (WFAS) (*//svinet2.fs.fed.us/land/wfas/*) web sites

The BLM's RAWS Program primarily collects meteorological data for fire weather forecasting. In past years, the network also provided considerable support to non-fire entities and is operated throughout the year. However, with increased pressure on operational dollars, the BLM Office of Fire and Aviation Management has decided to restructure its network. Plans were to reduce the fire network by about one-fourth in the western states. However, after considerable study and optimization, actual reductions have been about 15 percent. With continued funding pressures, the requirement to replace aging equipment, and the considerable costs associated with maintaining such a large network, BLM Fire Management's strategy was to reduce the total number of RAWS, move to a single station classification (all stations configured the same), operate only during the traditional western fire season (RAWS no longer maintained in winter months), and to use any savings in operating funds to replace aging equipment and upgrade the remaining network. However, once again, the expanded use of Fire Managements RAWS data set by other non-fire users has generated funding to permit year-round operation of the entire network. The BLM's Resource Management and Oregon O&C (West-Side) RAWS networks will continue to operate and be supported as in the past. These networks are much smaller and have specific program requirements that differ from fire management.

In 1997, the BLM began contracting with a private vendor via the National Weather Service (NWS) for lightning location data. Data is received at the NIFC in Boise, Idaho and placed on the BLM WFMIS for qualified user access. Current plans are to continue the operation of the Alaska Automatic Lightning Detection System as an independent government-owed and operated system.

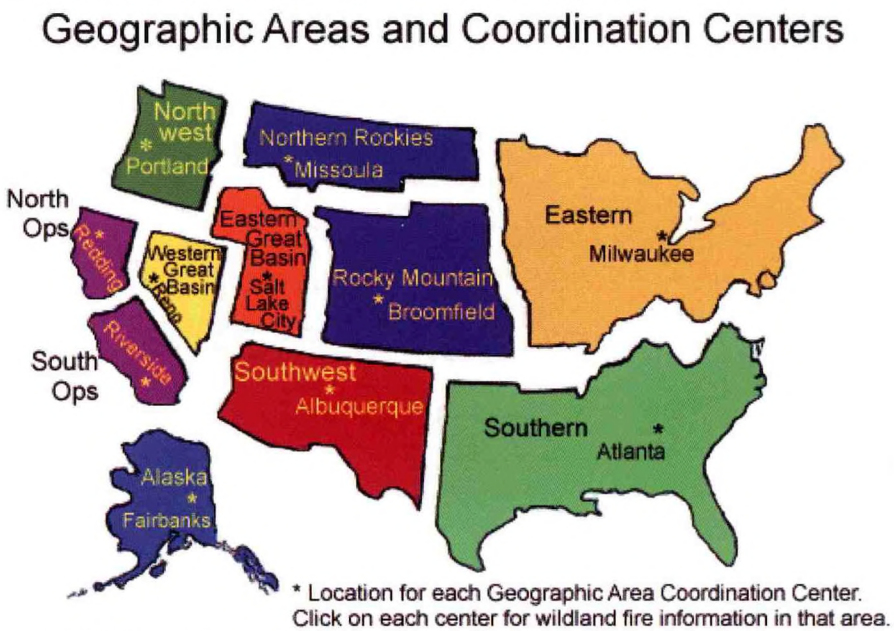


Figure 3-DOI-1. National Interagency Coordination Center coordinates with the GACCs for wildland fire supplies and resources.

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

In addition to the meteorological monitoring BLM conducts primarily to support wildland fire management activities, BLM also performs site-specific climate monitoring at over 200 manual weather station locations on the public lands in the eleven western states and Alaska. The operation of these sites ranges from seasonal to annual measurements of precipitation, temperature, soil moisture, and other meteorological parameters necessary to assess local climatic influences. These data are primarily used for natural resources management and planning at the local level.

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

National Park Service

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

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

United States Geological Survey

The Survey's Water Resources Division (WRD) collects streamflow, precipitation, and other climatological data for a number of projects concerning rainfall/runoff, water quality and hydrologic processes. Currently, the Geological Survey collects hydrometeorological data from approximately 5,130 remote data collection platforms (DCP). The data are transmitted to Wallops, Virginia, via GOES and rebroadcast to a domestic communication satellite (DOMSAT). Data are received from the DOMSAT by local readout ground stations (LRGS) procured by the Geological Survey under a 1992 contract. The USGS currently operates 15 LRGS' which provide near real-time data to the Survey's computerized National Water Information System. The USGS also collects precipitation samples in a number of studies for the determination of atmospheric contribution to the chemical constituent loads to runoff and for defining the effect of atmospheric deposition on water quality and the aquatic environment.

The USGS is continuing a joint research program with the National Aeronautics and Space Administration (NASA) and the Department of Agriculture (USDA) to map snowpack water equivalent or depth using satellite passive microwave observations from the Defense Meteorological Satellite Program SSM/I sensor. The satellite observations are being compared to snowpack data from a variety of sources: USDA's Natural Resources Conservation Service (NRCS) automatic Snotel sites; National Weather Service (NWS) sites; and observations by USGS field teams which include grain size, density, and stratigraphy. The object of the program is to develop algorithms to extract snow depth or water equivalent information from the satellite observations for near real-time assessments and for climatological studies using the two decade long satellite record. An algorithm has been developed which combines the satellite observations with surface temperature measurements to account for changing snowpack grain size--a factor that was not included in previous algorithms.

The Survey also carries out research in past climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity, and glaciology. As part of its glaciology program, the Survey maintains a benchmark pro-

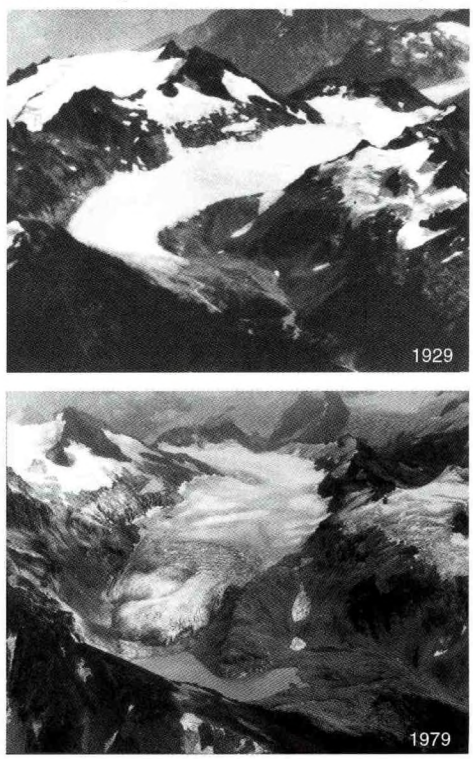


Figure 3-DOI-2. Aerial photographs capture the recession of the South Cascade Glacier in the State of Washington.

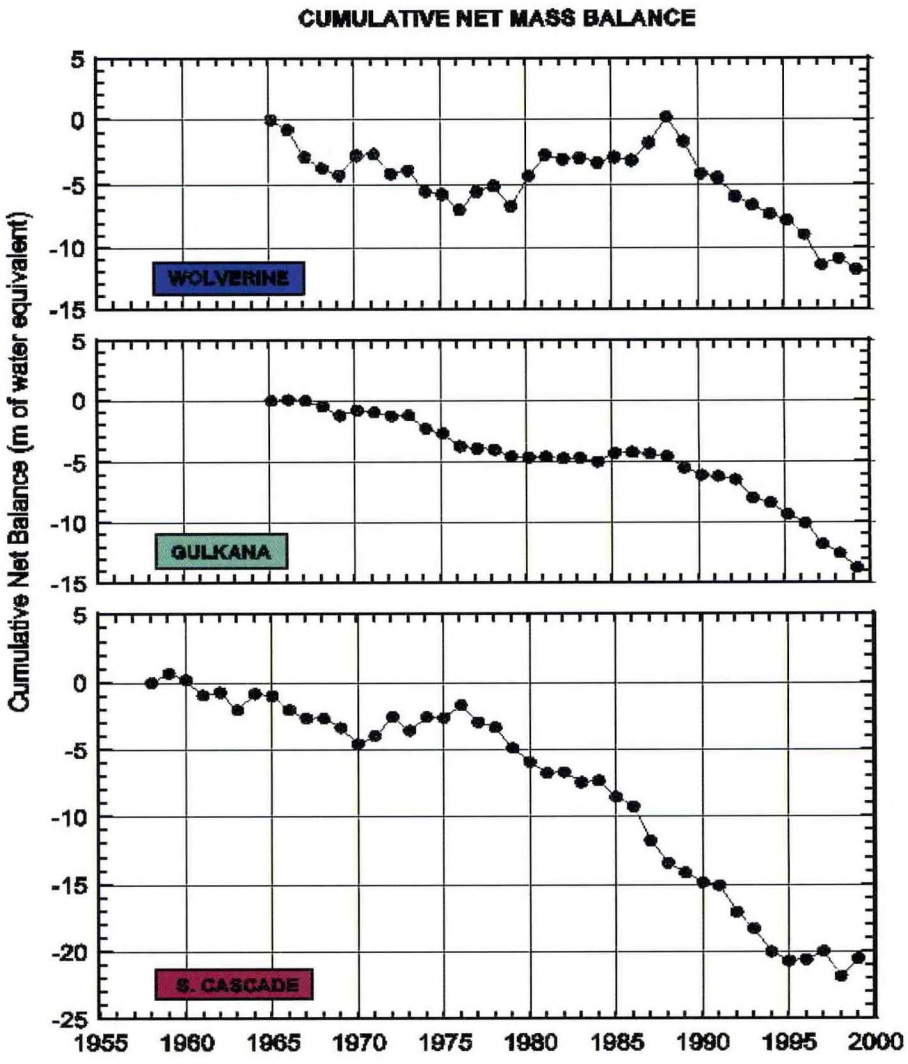


Figure 3-DOI-3. USGS monitors the decreasing mass of glaciers in Washington and Alaska.

gram on three benchmark glaciers representative of different climatic zones of the western United States--one in Washington (Figure 3-DOI-2), one on the south coast of Alaska, and one in the interior of Alaska. At each glacier, the program measures the winter snow accumulation, summer snow and ice ablation, air temperature, and runoff in the glacier basin. Analysis of this 37-year record is providing a greater understanding of the climate variability and its effects on water resources of the western United States. Both the snowpack and glaciology program now incorporate data supplied by the intelligence community through the coordination of the Civil Applications Committee (CAC) (Figure 3-DOI-3).

The Survey's Geologic Division, through the USGS Geomagnetism Group in Golden, Colorado, collects data on temporal variations of the Earth's magnetic field from a global network of over 70 geomagnetic observatories. These observatories (which include 14 operated directly by USGS) all belong to the INTERMAGNET program. Under INTERMAGNET, data from a global network of geomagnetic observatories are transmitted in near real-time via satellites and computer links (E-mail) to collection and dissemination points called Geomagnetic Information Nodes (GIN's). Five GIN's are now located in Europe, North America, and Asia.

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

The Survey participates in OFCM's Working Group for Volcanic Ash (WG/VA). This working group is preparing *A National Framework for Volcanic Ash Hazards to Aviation*. Through its Volcanic Hazards Program, the Survey is responsible for monitoring approximately 56 historically active volcanoes in the United States--44 are in Alaska. Until the 1980s, the Alaskan volcanoes had been largely unstudied. Despite the low population density of much of the state, Alaska's volcanoes underlie the heavily traveled air routes of the North Pacific region.

During recent years, the Survey's Alaskan Volcano Observatory (AVO) has expanded its network of real-time seismic monitoring stations. The expansion brought 21 of the state's volcanoes under continuous, real-time surveillance. Data and information from the AVO monitoring activities are integrated directly into the regional operational activities of the FAA, DOD, and NWS to provide warnings for pilots and aircraft operators in the Alaskan region.

Internationally, the OFCM WG/VA has supported expansion of the USGS

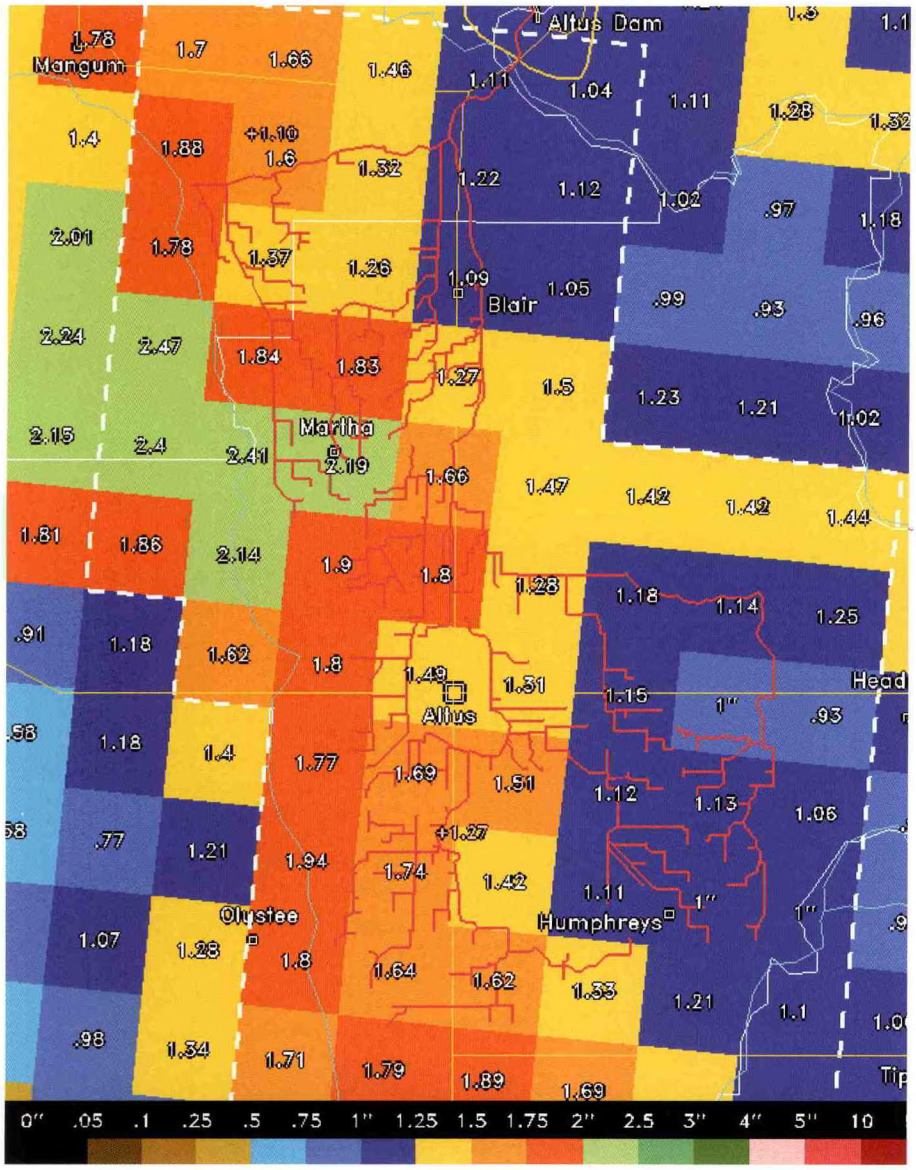


Figure 3-DOI-4. AWARDS System Interactive display enables users to click radar grid cells (within the white dashed line boundary) for a pop-up of the 24-hour estimated Crop Water Use charts. The user can also click on the weather stations for pop-up of the Daily Weather Data charts.

monitoring activities in the remote Pacific Rim of explosive volcanoes. The 100 historically active volcanoes in Alaska, Kamchatka, and the Kuriles are monitored through satellite imagery several times a day.

Currently, about 220 aircraft per day (carrying about 20,000 passengers and millions of dollars of cargo) transit the international Northern Pacific routes near these historically active volcanos. Approximately one-half these flights are United States carriers. AVO, through its working agreement with the Kamchatka Volcanic Eruption Response Team (KVERT) in Petropavlovsk-Kamchatsky, Russia, also supplies information about eruptive activity in Kamchatka and the Kuriles to the FAA, the NWS, and numerous domestic and foreign air carriers.

Bureau of Reclamation

The Bureau of Reclamation activities requiring the collection and use of meteorological data include water scheduling, flood hydrology, irrigation project management, and reservoir operations as well as projects related to hydroelectric energy resources. One example of this is the Agricultural Water Resources Decision Support (AWARDS) (*http://yampa.earthsci.do.usbr.gov:8080/awards/*) system. AWARDS integrates high-resolution NEXRAD radar rainfall estimates, surface environmental data, crop models, and quantitative precipitation forecasts with watershed reservoir-canal systems and irrigation district water distribution systems. AWARDS provides operational support for (1) early warnings to reduce hydrologic risk for loss of property and lives, (2) improved efficiency in canal and reservoir operations, and (3) improved efficiency in irrigation scheduling for water conservation and water quality.

The Rio Grande Basin AWARDS system has been modified to compute consumptive use of crops and riparian vegetation for irrigation diversions and reaches of rivers served in the Upper Rio Grande Basin. This activity is accomplished in close cooperation with the NWS Forecast Office, West Gulf River Forecast Center, and the multi-agency Upper Rio Grande Water Operations Modeling team. Daily results of this EvapoTranspiration (ET) Toolbox are posted on the internet for water managers, irrigation districts, and municipal water users. (*http://yampa.earthsci.do.usbr.gov:8080/awards/Nm/riogrande.html*) (Figure 3-DOI-4) Daily ET Toolbox calculations are also imported into RiverWare--the river basin water operations modeling system. Similar work is planned for the Yakima Basin where the ET Toolbox will also be linked directly to a daily water operations model to determine consumptive losses and depletions. These models assist water managers in water conservation decision-making. AWARDS systems are also being implemented for the Tualatin and Rogue River Basins in western Oregon and in the South Platte in northeastern Colorado.

Reclamation researchers finalized the NEXRAD Operational Support

Facility (OSF) report on the Snow Accumulation Algorithm (SAA). Researchers will continue improvement efforts and also apply the algorithm to Reclamation watersheds through their Research and Technology Transfer Program and NOAA's Global Energy and Water Cycle Experiment (GEWEX) Continental-Scale International Program (GCIP) cooperative partnership. GEWEX is part of the World Climate Research Program. The SAA development was a cooperative effort with the tri-agency WSR-88D OSF in Norman, Oklahoma. The prototype is being successfully field tested in the northern Plains from Minnesota to Montana on a daily basis and results are displayed on the Web for Reclamation's water managers as well as NWS forecasters and River Forecast Centers. Previous work demonstrated the prototype capabilities at Albany, New York, Cleveland, Ohio, and Minneapolis Minnesota. Work is planned to apply these algorithms and precipitation estimation techniques for the GEWEX Applications Prediction Program (GAPP) in the West beginning in FY 2002.

Reclamation's NEXRAD research team is also conducting cooperative work with the National Oceanic and Atmospheric Administration's (NOAA) GCIP. This work involves developing a correction scheme for known snowfall underestimation at far range caused by the curvature of the earth and the vertical profile of radar reflectivity. Reflectivity during snowfall has maximum values near the ground. In addition, Reclamation and GCIP are cooperating on providing snow water equivalent (SWE) estimates to the NOAA National Operational Hydrologic Remote Sensing Center which will incorporate them into their overall scheme of SWE and snow cover mapping for the nation. These spatial snow distributions are used by NWS River Forecast Centers and other agencies as input to runoff and streamflow models. Therefore, improved knowledge of SWE and snow cover distributions, resulting from including NEXRAD radar estimates, will provide more accurate steamflow forecasts. Improved forecasting will, in turn, allow better management of water resources.

Reclamation meteorologists are working on modifying their snow accumulation algorithm into a

Managing Water in the American West
(Bureau of Reclamation web site)

Precipitation Accumulation Algorithm (PAA). This algorithm will provide a means of real-time estimation of precipitation rates and water equivalent over areas of particular interest. For example, Reclamation water managers need real-time warnings concerning flash flooding into reservoirs for which dam safety is a concern. Another example is accurate estimation of rainfall onto irrigation districts as part of the AWARDS system discussed earlier.

Multi-agency work on projecting potential effects of climate change and climate variability on western water resources and Bureau operations is continuing under collaborative work with NOAA's GCIP, Office of Global Programs, and the National Centers for Environmental Prediction (NCEP). The NWS RFCs provide detailed streamflow forecasts for Reclamation's operations. Of note is technology transfer efforts in the Central Valley Operations Office in Sacramento, California, where a direct workstation link to the NWS River Forecast System and other hydrometeorological forecast products is providing Reclamation's water managers access to detailed products of immediate value to water management operations. This direct link to NWS products has proven invaluable for Central Valley Project Operations, particularly during periods of heavy precipitation and extreme events when timely information is readily available to water operations managers.

Other multi-agency studies are underway with the Los Alamos National Laboratory's remote sensing and coupled atmospheric and hydrologic modeling teams. Raman LIDAR measurements of water vapor fluxes over the riparian zones of the Bosque del Apache and crops are enhancing our knowledge of consumptive losses from salt cedar and cottonwood trees, and crop ET. Coupled modeling efforts to improve local mesoscale predictions of precipitation and runoff in the Upper Rio Grande Basin have begun using NCEP large-scale MRF models to initialize the Regional Atmospheric Modeling System and provide forecast stream flows using the USGS Modular Modeling System. This effort is part of the NSF sponsored Sustainable Semi-arid Science and Technology Center research at the University of Arizona.

Another collaborative effort is beginning with ERL's Climate Diagnostics Center's Western Water Initiative in collaboration with the Cooperative Institute for Research in Environmental Sciences (CIRES). This effort involves the validation, quantification of uncertainty, and development of water management applications for extended weather and climate forecasts. This Office of Global Programs sponsored research complements the GAPP and upcoming Water Cycles multi-agency applied

hydrometeorological research programs.

A Technology Advancement study of heavy precipitation events in collaboration with NCEP and the National Center for Atmospheric Research (NCAR) is examining the utility of mesoscale models for simulation and prediction of extreme precipitation events. These efforts are taking current technologies and applying them to very heavy precipitation events to determine maximum precipitation and better understand limits of extreme precipitation in watersheds above Reclamation facilities for safety of dams studies and early warning applications. Additionally, under the Technology Advancement program, Reclamation and representatives from the NWS Office of Hydrology are currently in the process of updating rainfall-frequency estimates for both the Ohio River Region and Upper Midwest Region of the United States. Results of these studies will eventually replace those estimates obtained in Technical Papers Nos. 40 & 49 (Weather Bureau 1961 and 1964, respectively).

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

Minerals Management Service

The Minerals Management Service's (MMS) Environmental Studies Program gathers offshore environmental data for use in the management of offshore oil and gas resources. Currently, MMS is funding the continued operation of five meteorological buoys which transmit data via NOAA satellites. Two buoys are located in the Gulf of Mexico and two in the Pacific Ocean off California. The MMS also utilizes data from other buoys funded by NOAA. The buoys collect air temperature, sea surface temperature, wind direction, wind speed, wave height, and wave spectrum data.

In FY 1998, the MMS started data collection from two 915-MHz profilers with RASS to study the atmospheric boundary layer over the Gulf of Mexico. One profiler is located on a platform about 6 miles off the central Louisiana coast; the other is placed in deeper waters about 130 km from shore. Hourly observations are transmitted to the NWS via GOES satellite on a real-time basis for use in prognostic models. Data collection started in June 1998 and will last for three years. Each site also collects surface data on wind, temperature, relative humidity, atmospheric pressure, and sea surface temperature. The MMS initiated a 3 year study to synthesize the data from the two profilers along with data from various other sources in the Gulf of Mexico and adjacent onshore area. The goal of this effort is to establish a data base on marine boundary layer and atmospheric dispersion characteristics in the Gulf.

The MMS has requested the offshore oil and gas industry to establish a network of meteorological stations in the offshore area around the Breton National Wilderness Area in Louisiana to collect data for air quality modeling. Meteorological surface data will be collected from a number of offshore platforms and buoys. In addition, three radar profilers with RASS will be installed to collect upper air data. This effort is being funded by industry and data collection is expected to start in April 2000. Data will be collected for one year.

Bureau of Indian Affairs

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

DEPARTMENT OF STATE CLIMATE AND ATMOSPHERIC PROGRAMS

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

Stratospheric ozone depletion has been recognized as a critical health and environmental problem for more than a decade. Under DOS leadership, the United States worked to negotiate international agreements to phase out ozone-depleting substances, which should lead to a recovery of the ozone layer in the next century. To date, these treaties have been signed and ratified by more than 170 countries (including the United States), representing 99 percent of the world's production of ozone depleting substances.

The IPCC, which is jointly sponsored by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), held its first session in 1988. This organization serves as a government forum to assess the state of scientific and technical information regarding climate change. The IPCC is currently organized in three working groups, examining: (1) the state of the science, (2) impacts and adaptation, and (3) mitigation. The IPCC released its first and second assessment reports in 1990 and 1995, respectively, and a third assessment report from each of the working groups is scheduled for publication in the middle of 2001. In addition to preparing assessment reports, the IPCC also contributed to international negotiations through preparation and review of special reports and development of methodologies requested by the Framework Convention on Climate Change (FCCC).

The FCCC was negotiated beginning in February 1991; the Convention was open for signature in Rio de Janeiro at the Earth Summit in June 1992. As of April 2000, it had been ratified by 184 countries, including the United States. The first meeting of the Conference of the Parties to the Convention was held in Berlin in March/April 1995. The Convention calls for all countries to develop inventories of their emissions and sinks of greenhouse gases and calls upon developed countries and economies in transition to aim to return these emissions to their 1990 levels by the year 2000. In December 1997, Parties to the Convention reached agreement on the Kyoto Protocol, which establishes targets for the reduction of greenhouse gas emissions in developed countries and countries with economies in transition.

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

ENVIRONMENTAL PROTECTION AGENCY WEATHER PROGRAMS

The Environmental Protection Agency (EPA) is responsible for working with state, local, and other federal government agencies to provide user-appropriate and scientifically credible air quality meteorological programs to support regulatory applications. Applied research and meteorological support are furnished primarily by the EPA National Exposure Research Laboratory and the EPA Office of Air Quality Planning and Standards, both located in Research Triangle Park, North Carolina. This activity is provided through interagency agreements with the National Oceanic and Atmospheric Administration (NOAA), which provides approximately 50 research meteorologists to the EPA.

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

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

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

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

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

Research in human exposure modeling includes microenvironmental monitoring and modeling, and development of exposure assessment tools. Microenvironmental algorithms are being developed based on field data to predict air quality in buildings, attached garages, and street canyons. These improved algorithms are then incorporated into microenvironmental simulation models for conducting human exposure assessments within enclosed spaces in which specific human activities occur.

In addition to these major areas, dispersion models for inert, reactive and toxic pollutants are under development and evaluation on all temporal and spatial scales, e.g., indoor, urban, complex terrain, mesoscale, and regional. Other efforts include construction and application of air pollution climatologies; modeling of agricultural pesticide spray drift and of fugitive particles from surface coal mines; modeling of trace metal deposition to the Great

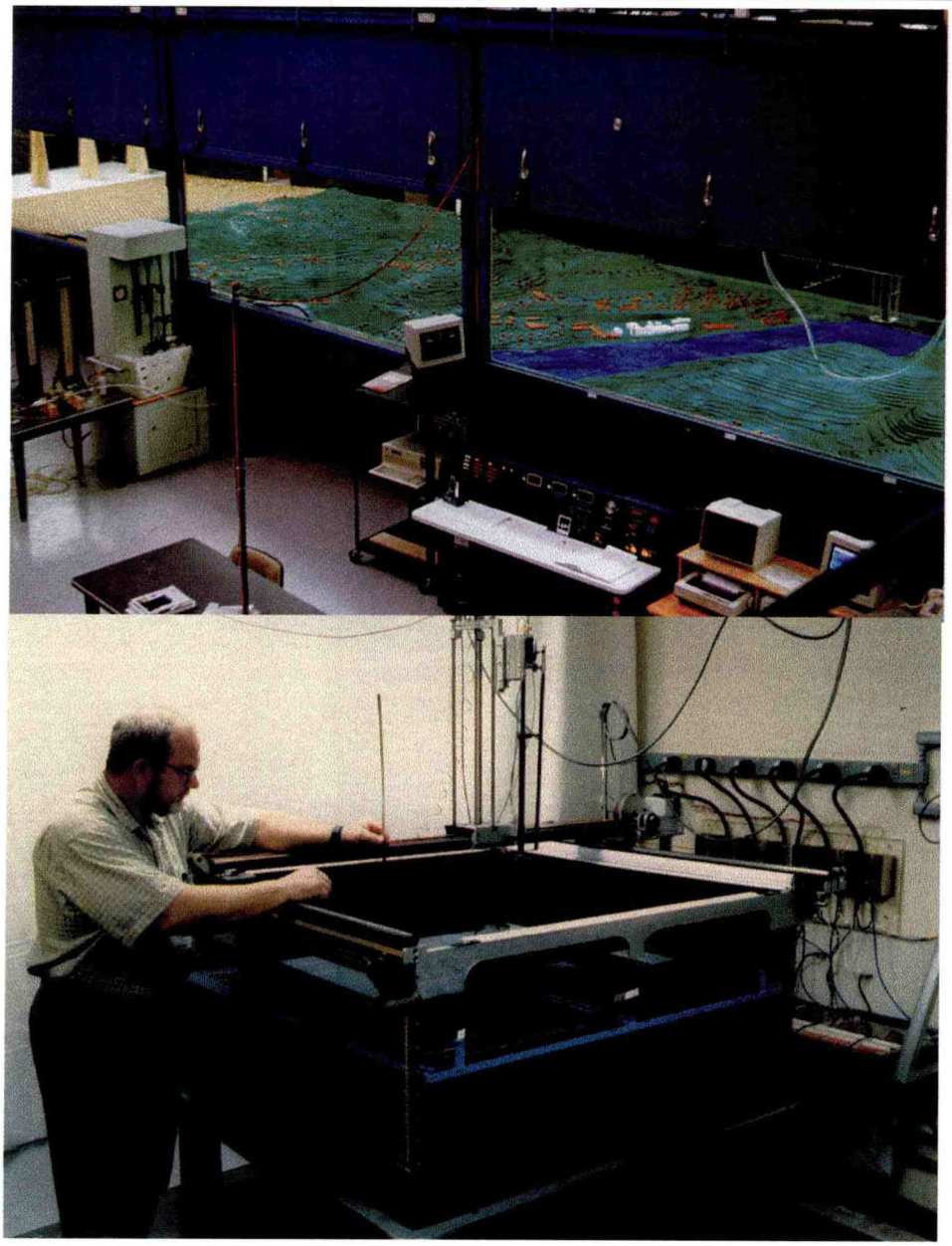


Figure 3-EPA-1. The EPA Fluid Modeling Facility conducts laboratory simulations of atmospheric flow and dispersion using a meteorological wind tunnel (top) and a convection tank.

Lakes, nutrient deposition to Chesapeake Bay, and mercury deposition to the Florida Everglades; modeling of accidental releases of toxic compounds forming dense gas clouds; determination and description of pollutant effects on atmospheric parameters; and conversely, determination of meteorological effects on air quality. Atmospheric flow and dispersion experimental data obtained from wind tunnel, water channel/towing tank, and convection tank experiments in the EPA Fluid Modeling Facility (Figure 3-EPA-1) will be used to continue development and evaluation of these models in the FY 2001-2002 period, along with providing researchers with insight into the basic physical processes that affect pollutant dispersion around natural and man-made obstacles. The convection tank will be used to simulate and develop improved models for open burning and open detonation of surplus and obsolete military munitions (Figure 3-EPA-2).

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

Over the past twenty-five years, numerous air quality simulation models have been developed to estimate reductions of ambient air pollutants resulting from potential emission control strategies. Separate models were developed, for example, for tropospheric ozone and photochemical smog, for acid deposition, and for fine particles. Distinct models also existed for addressing urban scale problems and the larger regional scale problems. It has been recognized, however, that the various pollutant regimes are closely linked chemically and spatially in the atmosphere. The principal purpose of the Models-3/CMAQ project was to develop a "one atmosphere" model that integrates the major atmospheric pollution regimes in a multi-scale, multi-pollutant modeling system, with high-level computational access by both sci-

entific and air quality management users for socio-economic applications in community health assessments and ecosystem sustainability studies.

After seven years of development, Models-3/CMAQ was released in June 1998 and is being updated annually for use by Federal agencies, States, industry, and academia. It is also intended to serve as a community framework for continual advancement and use of environmental assessment tools. Models-3/CMAQ is available on 8mm Exabyte tapes accompanied by an Installation and Operations Manual, a User Manual, a Science Document, and a Tutorial providing step by step instructions for use of the modeling capabilities. For more information, visit the Models-3 web site at *http://www.epa.gov/asmdnerl/models3/*

The evolving Multimedia Integrated Modeling System (MIMS) research seeks to improve the environmental management community's ability to evaluate the impact of air quality and watershed management practices, at multiple scales, on stream and estuarine conditions. Toward this goal the primary objectives are to (1) develop a prototype multiscale integrated modeling system with predictive meteorological capability for transport and fate of nutrients and chemical stressors; (2) enable the use of remotely sensed and monitored meteorological and air quality data, and process-based parameter estimation techniques in multiscale ecosystem assessment models; and (3) develop an easy to use computer-based problem solving environment with ready access to data, models, and integrated visualization and analysis tools for use in exposure-risk assessments, ecosystem restoration design, and policy development and refinement from regional to local scales. The MIMS development extends the open architecture approach demonstrated in the third generation modeling system, Models-3/CMAQ, to provide a framework for selecting meteorological, chemical, physical, and biological process components to build customized models for specific problems/domains, and to facilitate interaction among media specific models.

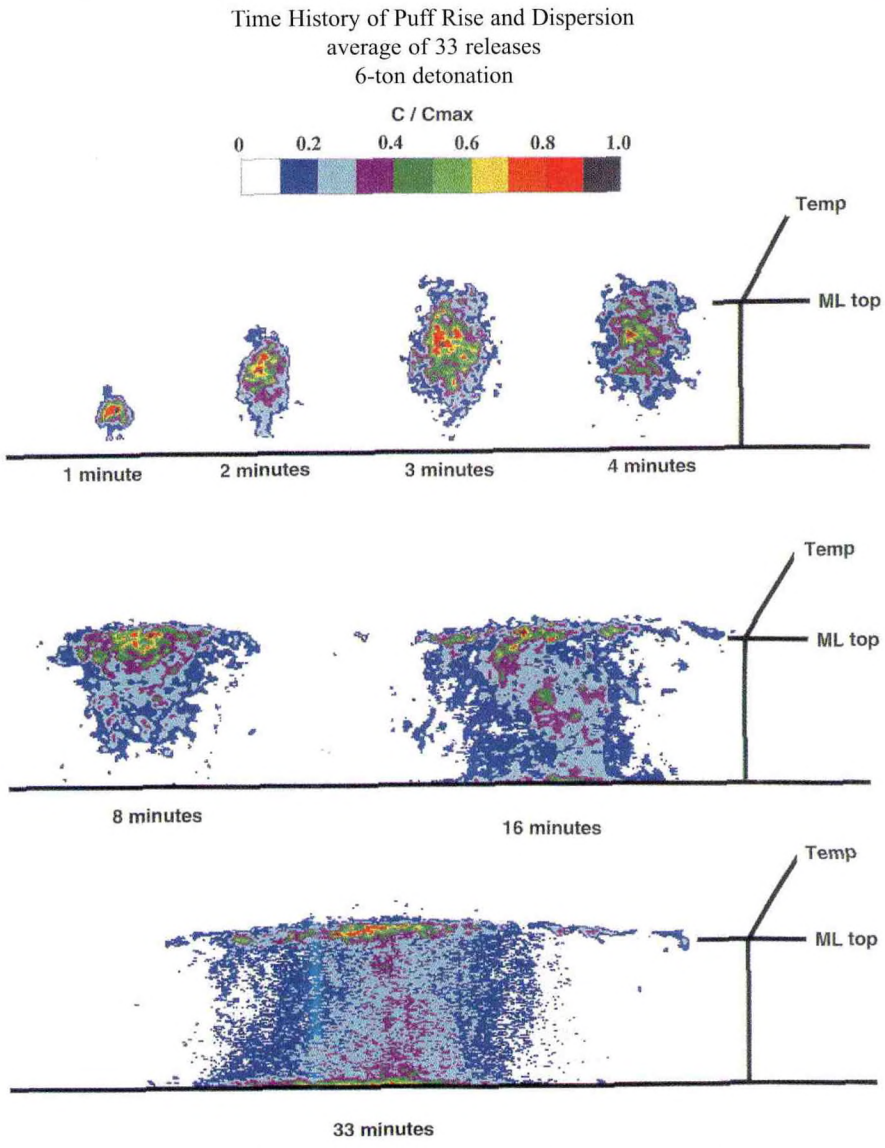


Figure 3-EPA-2. This series of photographs from a convection tank experiment shows the rise of a bouyant puff in a convection boundary layer capped by an inversion. These laboratory simulations were used to develop improved models for predicting the transport and fate of pollutants released during the open burning and open detonation of obsolete munitions.

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

FEDERAL EMERGENCY MANAGEMENT AGENCY WEATHER PROGRAMS

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

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

FEMA's priority interests with OFCM are in supporting FEMA's pre-disaster initiatives (including *Project Impact*) and in promoting standards and procedures which will enhance the ability of the Nation to mitigate and recover from emergencies and disasters. These interests extend to national standards for geographic information systems (GIS) used for delivery of meteorological products and services by other agencies. FEMA also actively supports the OFCM-sponsored Working Group for Post-Storm Data Acquisition (WG/PSDA) and the WG/PSDA's efforts to develop a *National Plan for Post-Storm Data Acquisition* to coordinate and support the collection, by the federal agencies, of perishable data after major storms. These data have potential applications in post-disaster mitigation activities, the NFIP flood hazard analysis, the FEMA National Hurricane Program hurricane evacuation studies, and other FEMA's risk analysis activities, such as the Multi-Hazard Loss Estimation Methodology (HAZUS). The Technical Services Division is the principal contact for hurricane evacuation studies and flood risk analysis as well as the FEMA contact point for meteorology-related matters. (*www.fema.gov*) (Figure 3-FEMA-1).

Figure 3-FEMA-1. FEMA Building performance assessment team viewing a damaged structure on Dauphin Island, Alabama.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WEATHER PROGRAMS

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

OPERATIONS

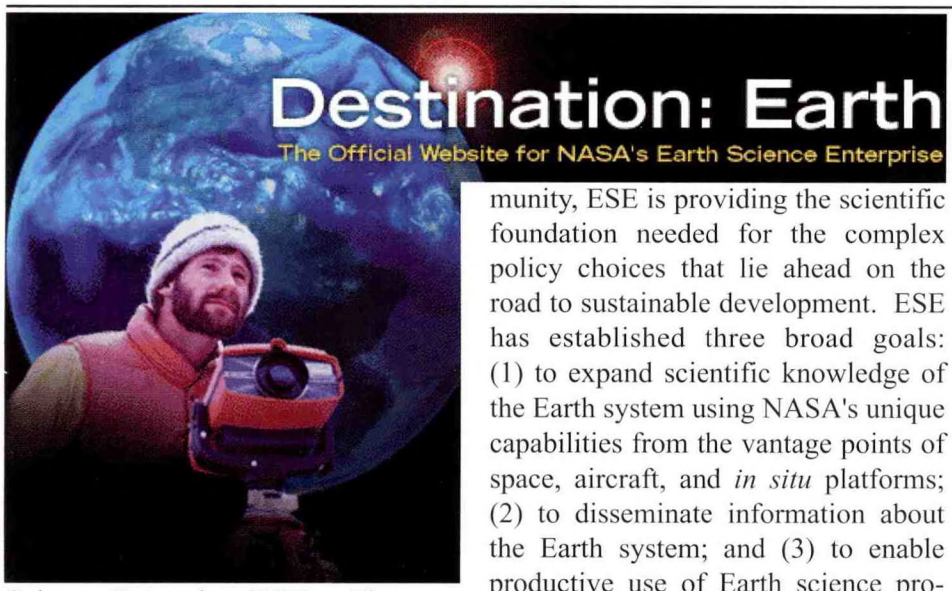
The goal of the National Aeronautics and Space Administration (NASA) operations program is to provide the specialized meteorological data needed by forecasters at Cape Canaveral Air Station and the Spaceflight Meteorology Group at Johnson Space Center (JSC) to support the Space Shuttle and Expendable Launch Vehicle programs. The focus is on detecting and forecasting the mesoscale weather events that strongly impact ground processing, launch, and landing operations.

This goal requires exploitation of the latest technology. The Applied Meteorology Unit (AMU), collocated with the Air Force's Range Weather Operations, provides a facility to evaluate and, if warranted, transition new meteorological technology into operations. For instance, the AMU strives to develop techniques and systems to help predict and avoid the impacts of Kennedy Spaceflight Center's (KSC) frequent mesoscale summer thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program-Space Shuttle, Department of Defense (DOD), and commercial. Special attention has been given to evaluating mesoscale numerical models. The AMU functions under a joint NASA, Air Force, and National Weather Service (NWS) Memorandum of Understanding. AMU tasks during FY 2000 include: (1) develop statistical short-range forecast tools and tools to forecast thunderstorm anvil development, movement, and dissipation; (2) provide technical advice to the Eastern Range (ER) on the procurement, development, testing, and integration of weather infrastructure items; (3) improve use and exploitation of the 5cm WSR-74C radar with SIGMET processor; (4) detect and analyze chaff signatures for source region(s); (5) analyze performance of the models that predict path of toxic and debris clouds after an unplanned explosion of a satellite launch rocket; (6) evaluate the ER Dispersion Assessment System (ERDAS), especially its meteorological component; (7) install the Local Data Integration System, developed by the AMU, at NWS and at JSC's Spaceflight Meteorology Group; and (8) provide technical advice to the Planet Mars Ascent Vehicle program (which will return samples from the Martian surface to earth), and on electric field measurements and lightning detection for incorporation into future Mars exploration programs.

The development of a new toxic model system ERDAS was completed in March 1999. NASA was the contracting agency for ERDAS development; funding was sent to NASA KSC by the Air Force. Operational implementation is complete. However, the AMU continues to work on Range Standardization and Automation (RSA). RSA is a major Air Force program to evaluate and document the day-to-day capabilities and limitations of ERDAS. Deliveries of weather sensors, models, and control and display systems began in FY 2000 and will conclude in FY 2001. Transfer of the KSC 50 MHz Doppler Radar Wind Profiler to the ER and modernization of its electronic components is proposed. There are considerable issues related to the pending changes to the Eastern and Western Ranges' meteorological infrastructures. The Air Force and NASA weather communities have expended considerable resources to solving potential major deficiencies. NASA KSC, JSC, and Marshall Space flight Center (MSFC) depend heavily on this infrastructure for their weather support.

SUPPORTING RESEARCH

The supporting research activities are sponsored by the NASA's Earth



Science Enterprise (ESE). The purpose of the ESE is to observe the global Earth environment, to understand the mechanisms that underlie natural and human-induced environmental changes, and to identify consequences that could impact human societies. In short, the purpose of the Enterprise is to provide scientific answers to the fundamental question:

> *How is the Earth changing and what are the consequences for human civilization?*

A fundamental discovery made during the 20th Century is the existence of a multiplicity of linkages between diverse natural phenomena and interactions between the individual components of the Earth system. As a result, a new "Earth system science" concept was developed, with the aim of investigating the complex behavior of the total Earth environment in which the global atmosphere, the oceans, the solid Earth and ice-covered regions of the Earth, and the biosphere all function as a single interactive system. Earth system science is an area of research with immense benefits to the Nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, ESE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. ESE has established three broad goals: (1) to expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft, and *in situ* platforms; (2) to disseminate information about the Earth system; and (3) to enable productive use of Earth science program science and technology in the public and private sectors. NASA has long been pursuing a vision of an interdisciplinary Earth system science. Traditional scientific disciplines have already progressed a long way in the study of the atmosphere, biosphere, land, and oceans as quasi-independent components of a stationary Earth system, while treating the interfaces between components as prescribed boundary conditions. Building on these scientific achievements, the strategy of Earth system science is to promote a "coordinated [research] effort between adjacent scientific disciplines and observation programs focused on common interrelated problems that affect the Earth as a whole" (*Toward an International Biosphere-Geosphere Program*; National Research Council (NRC), 1983). The ultimate goal of the NASA ESE is to achieve this synthesis and understand the interactive physical, chemical, and biological processes that govern the total Earth system. With this knowledge, NASA and its partners will develop prediction capabilities to quantify the effects of natural and human-induced changes on the global environment. Operational agencies, such as the National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS), who are partners in this effort, can use these capabilities to improve weather and climate forecasting, natural resource management, and other services on which the Nation relies.

STRATEGY FOR ACHIEVING GOALS

The first Earth Science Research Plan, published in 1996, laid out a strategy for study in five Earth system science areas of: (1) maturing scientific understanding and significant societal importance; (2) land-cover and land use changes; (3) short-term climate events, natural hazards research, and applications; (4) long-term climate change research; and (5) atmospheric ozone research. The plan also outlined some 20 related areas of research, which round out the Earth science contribution to Earth system science. NRC recognized the complexity of global Earth environment issues, the multiplicity of interactions between component processes and the cross-disciplinary connections they evoke (*Research Pathways for the Next Decade-Overview*; NRC, 1998). In the face of such complexity, the NRC outlined a diversity of unsolved scientific questions that call for further study, but also emphasized the need for a focused, scientific strategy, concentrating efforts and resources on critical scientific problems that are most relevant to national policy issues. Responding to the latter recommendation, the ESE is developing a targeted research program, focused on an updated set of specific science questions that can be addressed effectively with NASA's capabilities, and formulating comprehensive research strategies that can lead to definitive scientific answers, as well as effective applications of those scientific results.

The key research topics studied by NASA's ESE fall largely into three categories: forcings, responses, and the processes that link the two and provide feedback mechanisms. This conceptual approach applies in essence to all research areas of NASA's Earth sci-

ence program, although it is particularly relevant to the problem of climate change--a major Earth science-related issue facing the countries of the world. The ESE has articulated a set of science questions which its observational programs and research, modeling, and analysis activities are directed at answering.

§ *How does the Earth change naturally?*

§ *What are the primary forcings of the Earth system by human activities?*

§ *How does the Earth system respond to natural and human-induced changes?*

§ *What are the consequences of changes in the Earth system for human civilization?*

§ *How can we predict the changes in the Earth system that will take place in the future?*

NASA expects that expanded scientific knowledge of Earth processes and the utilization of advanced space-based and airborne observing techniques or facilities developed by NASA will result in practical applications beneficial to all citizens. Examples of these applications may include the prediction of impacts of environmental changes on fisheries, agriculture, and water resources; quantitative weather and hydrologic forecasts over an extended range of one-to-two weeks; and prediction of seasonal or longer-range climate variations, global air quality forecasts, and natural hazards risk assessments. NASA ESE has a role in demonstrating the potential applications.

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. NASA's Earth science research program comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive, and distribute global data sets; and research and analysis projects to convert data into new knowledge of the Earth system. Numerous users in academia, industry, federal, state, and local government use this knowledge to produce products and services essential to achieving sustainable development. Enabling us to get at the answers to the science questions, our top priority continues to be our existing near-term commitments with the launch of our first series of EOS and selected Earth probe missions that are nearing completion. In addition, NASA is committed to deliver a functioning data and information system to support the processing, archival, and distribution of data products for these missions. These satellites will propel the Enterprise into a new era of data collection, research, and analysis for which both the national and international Earth science community has been preparing over the last decade.

The Earth Observing System (EOS), the centerpiece of Earth science, is a program of multiple spacecraft (the Terra, Aqua (formerly PM), Chemistry, Landsat-7, Jason-1, ICEsat, ACRIMSAT and follow-on missions) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change. The first EOS satellite launches began in 1999. Preceding the EOS were a number of individual satellite and Shuttle-based missions that are helping to reveal basic processes. The Upper Atmosphere Research Satellite (UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer (TOMS) instruments, launched in 1978, 1991, and 1996, measure ozone distribution and depletion. Two TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System (ADEOS) mission and the other on a dedicated United States Earth Probe (Figure 3-NASA-1). France and the United States collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. QuikScat, which was launched after a one-year development, is providing measurements originally provided by the NASA Scatterometer (NSCAT), which mapped ocean winds for one year prior to an on-orbit failure of the Japanese ADEOS-I. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation. Also in 1997, ESE began purchasing ocean color data from a commercial vendor based on our joint investment in the SeaWifs instrument.

Figure 3-NASA-1. Artist drawing of ADEOS spacecraft in Earth orbit. (Source: NASA web site)

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy LIDAR (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The next ESSP missions were selected in December 1998. The first is the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations -Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) mission. The second is the CloudSat mission. Both are scheduled for launch in 2003. The scientific objectives of the

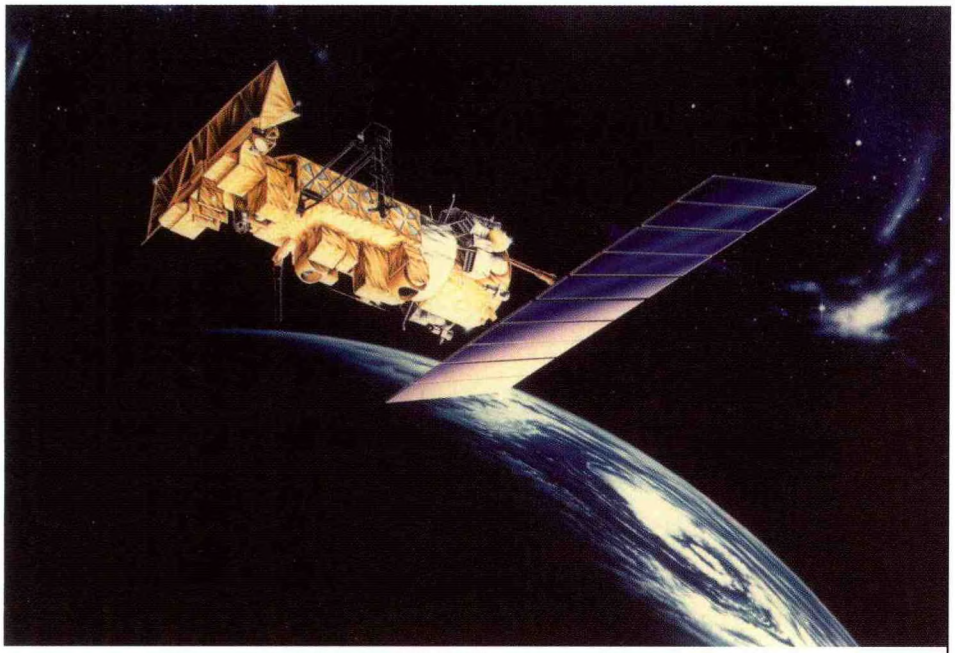


Figure 3-NASA-2. NPOES spacecraft in Earth orbit.

TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS Flight Model-5 has been completed and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, NASA has completed its re-planning and will be ready to fly FM-5, as QuikToms, on a United States vehicle and spacecraft in August 2000.

In developing its measurement/mission strategy, the ESE desires to reduce the risk to overall program objectives from any single mission failure by developing smaller, less expensive missions and implementing shorter development cycles from mission definition to launch. Shorter development times will allow more flexible responses to current and evolving scientific priorities and more effective uses of the latest technologies. In accordance with this philosophy, the implementation of each successive future mission in the ESE flight program will be based on specific solicitation alternatives (e. g. Announcement of Opportunity, Request for Proposal, etc.) and competitive selection of instrument payloads and implementation options. In each solicitation, NASA will ask commercial industry to come forward and offer science-quality data that meet NASA requirements. It is important, under this new approach, that instrument technology developments be conducted largely before the relevant mission payload selection. A science and applications-based, space-based measurement concept set is indispensable to guide these pre-mission technology developments, particularly, the Enterprise's Instrument Incubator Program. Our goal is to reach a mission development cycle of 2-3 years from the time of selection.

NASA ESE is developing a science implementation plan, which will drive the selection of Earth observation satellite missions in the 2003-2010 time frame. An early, high priority in this time frame is the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP). NPP will provide continuity with the Terra and Aqua missions as well as serve as a demonstration of instruments for the converged weather satellite program (Figure 3-NASA-2). NASA and the Integrated Program Office (IPO) jointly fund the NPP mission. The IPO consists of representative from the three agencies participating in NPOESS - NASA, NOAA, and the Air Force.

Data from Earth science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. Since these data are expected to find uses well-beyond the Earth science research community, EOSDIS will ultimately be accessible by environmental decision-makers, resource managers, commercial firms, social scientists, and the general academic community, educators, state, and local government--anyone who wants the information.

Following the recommendation of the NRC, NASA is exploring the creation of a federation of Earth science information partners in academia, industry, and government to broaden the participation in the creation and distribution of EOSDIS information products. As a federation pilot project, 24 organizations were competitively selected in December 1997 to become Earth Science Information Partners (ESIPs) to develop innovative science and applications products. This effort is part of a broader analysis of how ESE's approach to data and information systems services should evolve in the future.

The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. Over 1,500 scientific research tasks from nearly every state within the United States are funded by the Earth science research and analysis program. Scientists from seventeen other nations, funded by their own countries and collaborating with United States researchers, are also part

of the Earth science program. These researchers develop Earth system models from Earth science data, conduct laboratory and field experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our planet. ESE-funded scientists are recognized as world leaders in their fields, as exemplified by the award of the 1995 Nobel Prize in chemistry to two scientists who first recognized that cholorflorocarbons provided a threat to upper atmospheric ozone (Figure 3-NASA-3). The research and analysis program is also the basis for generation of application pilot programs that enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

From FY 2000 on, there is increased emphasis on a viable Applications, Commercial, and Education (ACE) program that bridges our focused research and analysis and mission science investments with the Applications and Commercial Remote Sensing Program towards demonstration of new remote sensing data products for industry and regional and local decision-makers. The need is to focus on the dissemination of information to non-traditional Earth science customers, such as states, counties, and regional managers and decision-makers. This budget identifies initial funding requirements for the Digital Earth Initiative designed to develop usable, remote sensing-based information products for state and local users around the Nation and beyond. A base program is funded to put the essential tools in place and pilot several key demonstration projects. Eventually, NASA anticipates that our demonstration of this concept will allow products to reach a much broader user base--practically every state in the Union.

The challenges of Earth System Science, sustainable development, and mitigation of risks to people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international partners. NASA's Earth science research program constitutes its contribution to the United States Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change. The USGCRP coordinates research among ten United States government agencies.

NASA is by far the largest partner in the USGCRP, providing the bulk of USGCRP's space-based observational needs. NASA has extensive collaboration with the NOAA on climate-related issues. The ESE is the responsible managing agent in NASA for the development of NOAA's operational environmental satellites. NOAA, NASA, and DOD jointly work to achieve the convergence of civilian and military weather satellite systems. NASA collaborates with the USGS on a range of land surface, solid Earth, and hydrology research projects. NASA and USGS collaborate in the Landsat-7 program and NASA, DOD, and USGS are working together on a third flight of the Shuttle Radar Laboratory modified to yield a digital terrain map of most of the Earth's surface. NASA participates in the World Climate Research Program, the International Geosphere/Biosphere

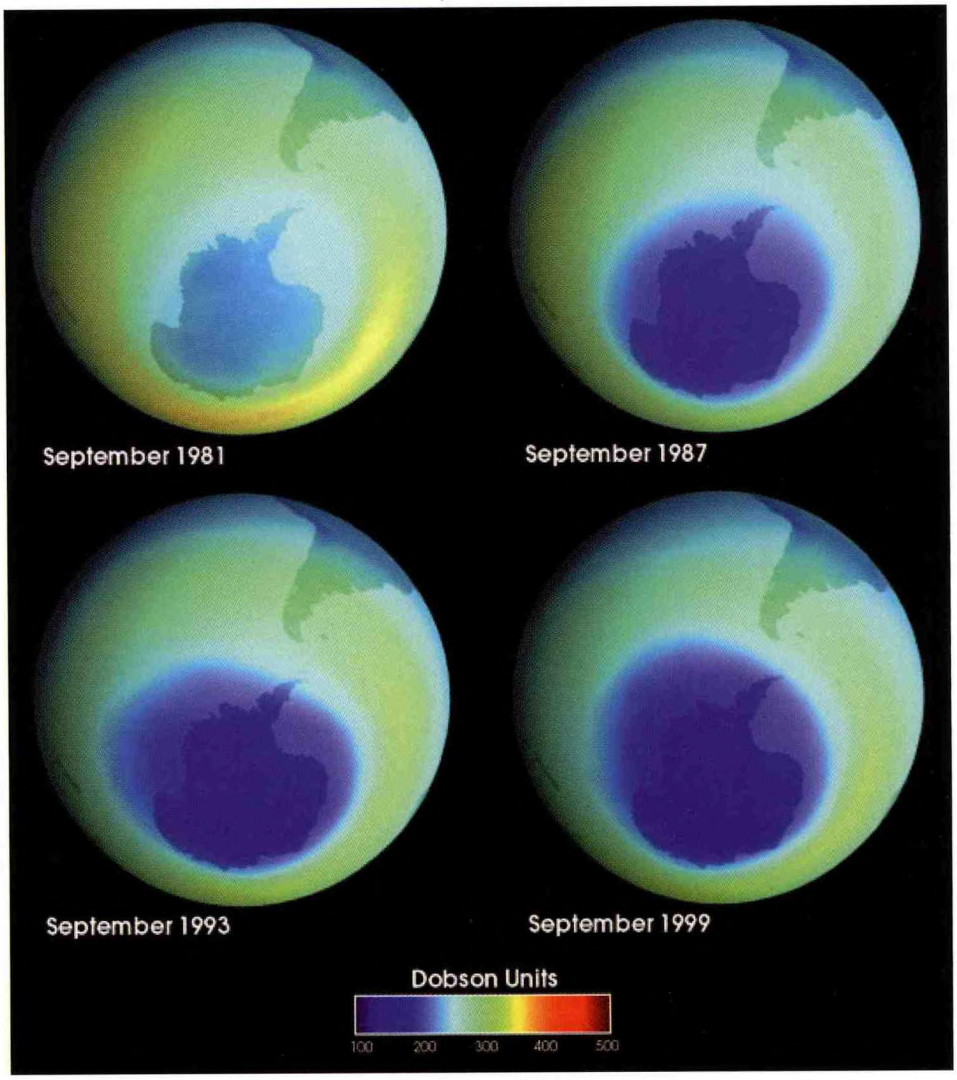


Figure 3-NASA-3. Observations of the Antarctic Ozone hole by NASA's Total Ozone Mapping Spectrometer (TOMS) Earth Probe show the progressive depletion of ozone. Values below 150 Dobson units indicate extremely low levels.

Program, and the ozone assessments of the World Meteorological Organization.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international involvement in its implementation and application. Acquiring and analyzing the information necessary to address the science questions is a bigger task than a single nation can undertake. Furthermore, the acceptance and use of the scientific knowledge in policy and resource management decisions around the world require the engagement of the international scientific community. Global data and global participation are needed to devise a global response to environmental change. In addition, integrating our complementary science programs can result in fiscal benefits to the NASA program. For this reason, NASA has sought and nurtured international partnerships spanning science, data and information systems, and flight missions. Most of Earth science's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. In the past three years, over 60 international agreements have been concluded and more than 40 more are pending. In some capacity, Earth science programs involve international partners from over 35 nations including Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, Denmark, Egypt, France, Germany, India, Israel, Italy, Japan, Mongolia, Russia, South Africa, Ukraine, and others.

In addition to ensuring a robust science program, this budget contains a vigorous Advanced Technology program that supports development of key technologies to enable our future science missions. In addition to our baseline technology program that includes the New Millennium Program (NMP),

Figure 3-NASA-4. Terra mission logo (Source: GSFC Web site)

Instrument Incubator and High Performance Computing and Communications (HPCC), an Advanced Technology Initiative will identify and invest in critical instrument, spacecraft, and information system technologies.

The ESE will lead the way in the development of highly capable, remote and *in situ* instruments and the information system technologies needed to support coupled Earth system models. Together, they will enable affordable investigation and broad understanding of the global Earth system. The ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from hundreds to tens of thousands, with the goal of providing easy access to global information for science, education, and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial enterprises.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance, and timeliness of future Earth science process and monitoring campaigns. ESE's strategy is to establish strong links to other government programs in order to maximize mutual benefit to use open competitions for ESE-sponsored technology programs to attract the best ideas and capabilities from the broad technology community, including industry and academia. Technology efforts will be made in the following areas:

- Advanced instrument and measurement technologies for new and/or lower cost scientific investigations;
- Cutting-edge technologies, processes, techniques, and engineering capabilities that reduce development, operations costs, and mission risk and that support rapid implementation of productive, economical, and timely missions;
- Advanced end-to-end mission information system technologies: technologies affecting the data flow from origination at the instrument detector through data archiving for collecting and disseminating information about the Earth system, and enabling the productive use of Enterprise science and technology in the public and private sectors.

Terra (formerly AM) was recently launched on December 18, 1999 (Figure 3-NASA-4). Terra will provide key measurements that will significantly contribute to our understanding of the total Earth system. The instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 was also launched in 1999. Landsat-7's single instrument, the Enhanced Thematic Mapper Plus (ETM+), is making high spatial resolution measurements of land surface and surrounding coastal regions. This mission is successfully providing data continuity with previous Landsat measurements. Landsat data is used for global change research, regional

environmental change studies, and other civil and commercial purposes.

With the EOS missions, such as QuikScat, Terra, Landsat-7, and ACRIMSAT that were launched in 1999, NASA is beginning to turn flight data into information. In addition to the EOSDIS that will produce data products for a wide range of users, NASA is engaging in a variety of activities to extend the utility of Earth Science data to a broader range of users, such as regional Earth science applications centers and Earth science information partners. Efforts are also under way to fuse science data, socio-economic data, and other data sets that can be "geo-referenced" in readily understandable data visualizations.

The first of two cooperative missions with the Russian Space Agency (RSA), the Meteor-3M (1) Stratospheric Gas and Aerosol Experiment (SAGE III) mission, had been planned for launch in 1999. At this time, it is uncertain that the Russians will meet their commitment to be ready to launch SAGE III in FY 2000. The instrument is completed and in storage at LaRC in the meantime but will not be shipped due to safety-related issues until the spacecraft is ready to accommodate its integration. This mission will collect global profiles of key gaseous species from the troposphere to the mesosphere. The science team will investigate spatial and temporal variability and investigate the effects of aerosols and clouds on the Earth's environment. The Russian METEOR-3M (2) spacecraft had planned to carry the last planned TOMS into orbit in 2000, providing continuity in the essential measurement of the total column of ozone in the stratosphere. This past year, NASA learned that Russia would not be able to meet its goals for producing a spacecraft and launch vehicle for the TOMS instrument. Since then, NASA and the RSA mutually agreed to terminate cooperative activities on the project. NASA is currently implementing QuikToms using an United States provided launch vehicle and spacecraft.

The QuikScat spacecraft was launched in April 1999. QuikScat, carrying instruments to collect sea surface wind data, is filling the gap in such critical data between ADEOS-I, which failed in June 1997 after seven months on-orbit, and ADEOS-II. The availability of components of the Seawinds instrument originally planned for launch on Japan's ADEOS II was accelerated to fly on QuikScat. Japan has yet to decide on the timing and form of an ADEOS II mission (or missions), but the ESE still intends to fly a Seawinds instrument in that context as the follow-on instrument to QuikScat. It now appears that ADEOS-II will be launched no earlier than late 2001 with the delay due in part to a failure of a Japanese launch vehicle.

The Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) was launched on December 20, 1999 providing for the continuation of the long-term, quantitative understanding of the solar forcing of Earth's climate.

The measurements to be made by these and other future Earth science missions as well as current on-orbit missions provide data products that are used extensively in the Earth science program. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

AVIATION WEATHER RESEARCH

NASA is performing research that will substantially improve the display of weather information in the cockpit, will provide dramatic improvements in synthetic vision (electronic vision aids to see at night in poor visibility), turbulence detection, and icing protection. The research applies to commercial aviation as well as general aviation. Some of the research makes extensive use of data from the Global Positioning System (GPS) satellite network.

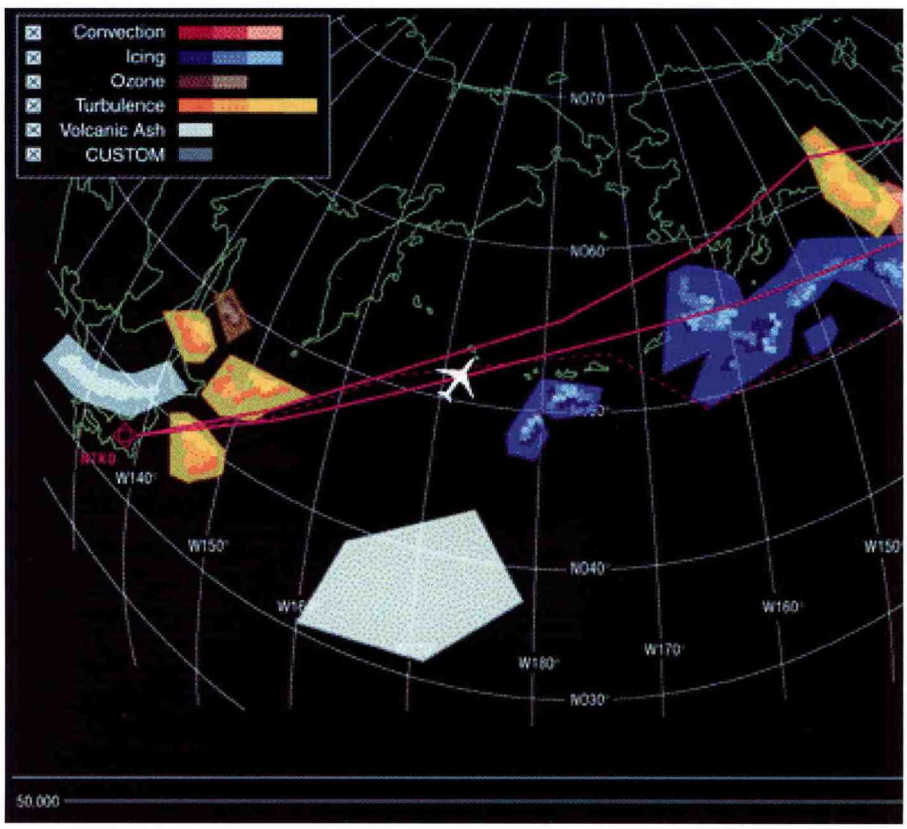


Figure 3-NASA-5. Aviation Weather Information Cockpit display.

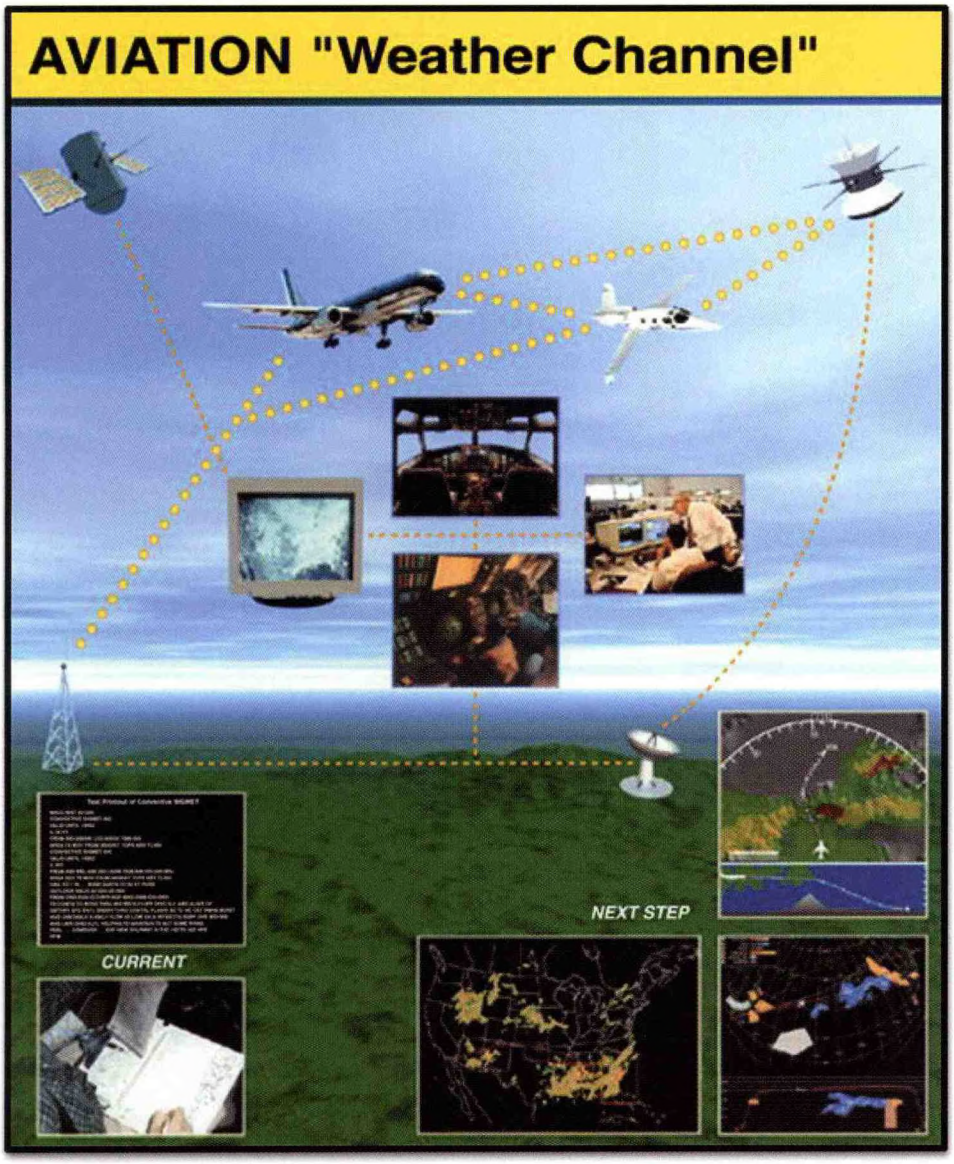


Figure 3-NASA-6. Communication and distribution channels for Aviation weather information.

Aviation Safety Program

NASA's Aviation Safety Program is aggressively pursuing three primary areas:

- Aviation Weather Information Distribution and Presentation: This effort includes combining the inputs from a variety of sources of weather data into a convenient, cockpit display that is simple and easy for the pilot to comprehend. It will likely be a multi-function flat panel display that will display all forms of weather, terrain and traffic hazards (Figure 3-NASA-5 and Figure 3-NASA-6).
- Synthetic Vision in the Cockpit: Synthetic Vision is electronically enhanced vision for the pilot. It combines a very detailed world wide terrain map (obtained from a recent Space Shuttle mapping mission), precise GPS navigation data, and integrity-monitoring sensors to provide a realistic view of the world through a cockpit head-up-display (HUD) or panel mounted display. The pilot will look through the HUD as he or she looks out the window. This see-through HUD will make the world look like a bright sunny day even when the airplane is approaching a fogged-in airport at midnight--one that would be shut down under today's operating rules.
- Turbulence Detection: This project is the development of aircraft-mounted, forward looking turbulence detectors that look several kilometers ahead of the aircraft using Lidar and radar sensors. A suitable cockpit warning device would alert pilots of impending encounters. There is also work in ground based detection (Figure 3-NASA-7).

NASA's Icing Research is pursuing a large number of areas that affect aircraft in flight. Primary examples of this effort are:

- The development of icing training videos and other materials will help educate pilots on all aspects of aviation icing.
- The development of improved wind tunnel and analytical techniques to predict icing accumulation patterns on wings, tails, and inlets will help designers improve future aircraft and engines.
- Forward looking, aircraft mounted detectors will detect moisture laden clouds miles ahead of the aircraft. Adding air temperature, pressure, and humidity to the data received from the sensors, computers will compute the icing potential of the approaching cloud and will display "high risk areas" to the pilot in an easily read, color cockpit display.
- Sensors that measure the accumulated ice on aircraft in-flight will automatically activate, new, low cost de-icing devices that will shed the ice before the aircraft gets in danger.
- The potential for satellite detection of icing conditions is being investigated.

General Aviation

NASA's General Aviation element is actively researching new, low power, and low cost pneumatic and electrical ice removal technology. Also in development are low cost displays that

graphically show icing weather information so icing conditions can be avoided during flight planning.

Terminal Area Productivity

NASA's Terminal Area Productivity element is contributing via these areas (program ends September 30, 2000):

- Wake vortex detection/prediction to improve the efficiency of aircraft spacing.
- A heads up display that electronically displays the edges of taxiways and runways, shows ground traffic and marks clearance routes to gates and/or runways. All this is overlaid on the pilot's "real world" view out the window while stereo headphones allow the pilot to hear ground traffic from the direction the other aircraft really are. This technology will be a great aid to vision in poor visibility--especially at unfamiliar airports.
- A look down electronic display shows a bird's eye view of the airport as if the pilot were looking at the airport on a bright sunny day from about 1,000 feet above the airport. The position of all runways, taxiways, buildings, and ground traffic is clearly displayed--as is the exact route the pilot is cleared to take to get to the gate or the runway. Another huge aid to vision in bad weather.

As with virtually all of NASA's aviation research, most of the research mentioned above also helps pilots in good weather too.

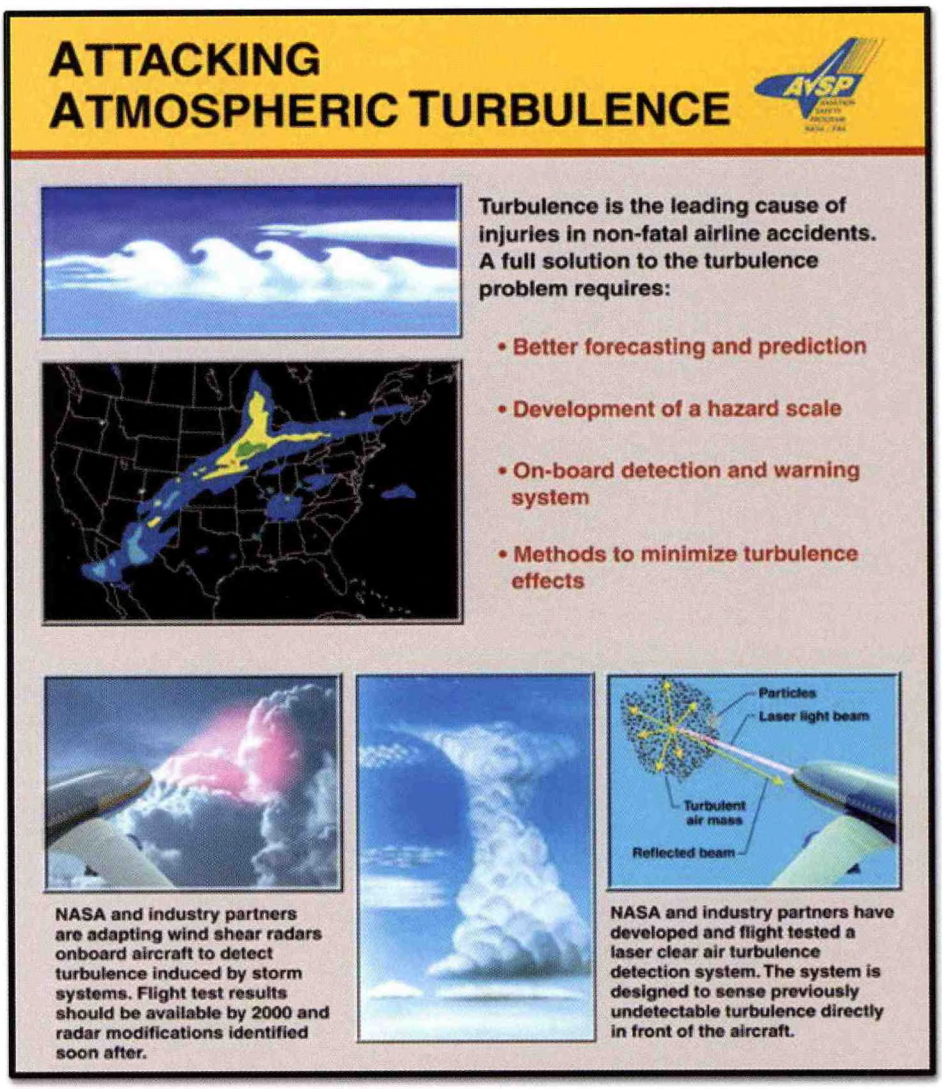


Figure 3-NASA-7. NASA's Aviation Safety Program plans to detect atmospheric turbulence through the use of advanced technologies.

NUCLEAR REGULATORY COMMISSION WEATHER PROGRAMS

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

Within the NRC, the Office of Nuclear Reactor Regulation and the Office of Nuclear Material Safety and Safeguards conducts reviews of facility siting, design, construction and operation of nuclear facilities as well as conducting rulemaking to establish regulatory requirements. These reviews include consideration of meteorological factors. The NRC Regional Offices assure that commitments by NRC licensees are carried out and, with NRC Incident Response Operations, also conduct NRC responses to nuclear facility emergencies. The Office of Nuclear Regulatory Research conducts research activities to identify potential safety issues and to provide the technical basis to address these issues and to prepare the agency to regulate the use of new technology. The Office of Research also develops regulatory guidance and participates in the development of criteria and consensus standards related to the protection of the public health and safety and the environment.

The primary meteorological area in which the NRC will have an interest during FY 2001 and beyond is improvements in the meteorological capabilities of the NRC and the operators of nuclear facilities to cope with emergencies involving the unplanned releases of radioactive materials. In addition, meteorological data will be used to provide input to the assessment of the radiological impacts of routine airborne releases from facilities and the assessment of the potential radiological impacts of engineering changes in plant design or operation proposed by licensees should unplanned releases occur. Also, this information is important to assess the climatological impacts on the isolation of long-lived wastes. The NRC also maintains an interest in the transport and dispersion of airborne, hazardous non-radioactive materials and extreme and severe meteorological events and their potential effects on the safe operation of nuclear facilities.

Figure 3-NRC-1. NRC is responsible for licensing activities for a potential high level waste repository located at Yucca Mountain, Nevada. (Source: NRC Website)

NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent agency of the Federal Government established to promote and advance scientific and engineering progress. The NSF sponsors and funds scientific and engineering research and education projects and supports cooperative research to gain new understanding of the behavior of the Earth's atmosphere and oceans. NSF does not itself conduct research but funds research performed by scientists at universities and other entities. In addition, NSF provides support for the maintenance and operation of the National Center for Atmospheric Research (NCAR) which is devoted to large-scale atmospheric research projects conducted in cooperation with universities and other federal, state and/or local organizations.

The Division of Atmospheric Sciences manages NSF's basic atmospheric research support. This research focuses on new and fundamental knowledge needed to better understand the atmosphere and related sciences and to manage atmospheric science programs including natural disaster reduction, space weather, global change, and air quality.

Natural Disaster Reduction. NSF supports two interagency programs under natural disaster reduction and mitigation: the United States Weather Research Program (USWRP) and the National Space Weather Program (NSWP).

The USWRP is an interagency effort to perform the research and technology transfer needed to improve the delivery of weather services to the country. Participating agencies include NSF, National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA) and Navy's Office of Naval Research (ONR). NSF supports fundamental and applied research to meet the USWRP objectives. Initial foci are:

- better understanding and forecasting of hurricane track and intensity;
- better quantitative precipitation forecasting;
- optimal use of observations in numerical models; and
- the societal/economic impacts of improved weather information.

The total research support for FY 2000 was $13.9 million. In FY 2001, support of this research is expected to be $13.9 million.

The objective of the NSWP is to perform the research and technology transfer needed to improve the specification and forecasts of space weather events that can cause disruption and failure of space-borne and ground-based technological systems and can endanger human health. Participating agencies are: NSF, NASA, NOAA, Federal Aviation Administration (FAA), Department of Defense (DOD) -Air Force and Navy's ONR, Department of Energy, and Department of the Interior. The FY 2000 shared budget was $14.0 million with NSF supplying $2.4 million. The total funding for FY 2001 is expected to increase slightly to $2.7 million.

Global Change. Under the United States Global Change Research Program (USGCRP), NSF programs support research and related activities that advance fundamental understanding of dynamic physical, biological, and socioeconomic systems as well as interactions among those systems. In addition to research on Earth system processes and the consequences of changes in those systems, NSF programs facilitate data acquisition and data management activities necessary for basic research on global change, promote the enhancement of modeling designed to improve representations of Earth system interactions, and develop advanced analytic methods to facilitate fundamental research. NSF also supports fundamental research on the general processes used by governments and other organizations to identify and evaluate different types of policies for mitigation, adaptation, and other responses to changing global environmental conditions. The total NSF FY 2000 USGCRP funding was $181.7 million and in FY 2001 is expected to be $181.7 million. The Division of Atmospheric Sciences USGCRP funding for FY 2000 was $44.0 million with FY 2001 funding expected to be $44 million.

Air Quality. NSF supported fundamental research in the area of air quality helps develop improved understanding of the sources, formation, and atmospheric processing of ambient air pollutants. Atmospheric oxidant species (and their precursors), sulfur dioxide, nitrogen oxides, carbon monoxide, fine particles, and acid deposition (and its precursors) are important atmospheric constituents that influence air quality. Field experiments, laboratory studies, instrumentation development, new methods of chemical analysis, and improved models of atmospheric chemical transport and depositional phenomena are examples of air quality research supported by NSF. These categories provide scientific and technical input for management and control of atmospheric pollutant gases and particles. NSF funding for FY 2000 was $1.5 million and is expected to stay the same for FY 2001.

NOTE: NSF budget data is not captured in Tables 2.1-2.5.

APPENDIX A

FEDERAL COORDINATION AND PLANNING

BASIS FOR FEDERAL COORDINATION PROCESS

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

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

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

MISSION AND STAFFING OF THE OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY

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

These objectives include:

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

DOC currently has ten positions assigned to OFCM. DOC also provides administrative support to OFCM and approximately one-half of OFCM's annual operating budget. The Department of Defense (DOD) currently provides two senior staff officers--one Air Force and one Navy--and contributes approximately one-fourth of the annual operating budget. The Department of Transportation (DOT) Federal Aviation Administration (FAA) provides one professional staff member and also provides approximately one-fourth of the annual operating budget. These three agency representatives are designated Assistant Federal Coordinators for liaison to their respective agencies. In all, 13 meteorologists, oceanographers, physical scientists, and administrative and computer-support personnel are assigned to the OFCM staff.

FEDERAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

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

The 15 federal agencies that engage in meteorological activities or have a need for meteorological services are represented on FCMSSR. The FCMSSR membership includes: DOC, DOD, DOT, the Departments of Agriculture (USDA), Energy (DOE), Interior (DOI), and State (DOS), and the Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), National Transportation Safety Board (NTSB), Nuclear Regulatory Commission (NRC), the Office of Science and Technology Policy (OSTP), and the Office of Management and Budget (OMB).

HIGHLIGHTS FOR FISCAL YEAR 2000 AND PLANS FOR FISCAL YEAR 2001

NATURAL DISASTER REDUCTION

54th Interdepartmental Hurricane Conference (IHC) (February 14-18, 2000)

OFCM annually hosts the Interdepartmental Hurricane Conference to provide a forum for the responsible federal agencies, together with representatives of the user communities such as emergency management, to review the nation's hurricane forecast and warning program and to make recommendations on how to improve the program in the future. Houston, Texas was chosen as the site for the 54th IHC to commemorate the 100th anniversary of the 1900 hurricane which devastated the Galveston/Houston area. The theme for the conference was "*20th Century Highlights and Prospects for the Future*". An important objective of the conference was to more closely link hurricane operations with ongoing research efforts. Revisions were made to the *National Hurricane Operations Plan* which provides the basis for hurricane reconnaissance and forecast and warning operations for the 2000 season. Workshops included hurricane inland flooding, transitioning research to operations, weather reconnaissance of the future, and improving user community coordination. A ceremony commemorating the 1900 storm was planned in conjunction with the Galveston Historical Foundation and hosted by the Honorable Roger Quiroga, Mayor of Galveston, on Thursday afternoon, February 17, 2000.

1900 Galveston Storm Commemoration

OFCM made arrangements for the Under Secretary of Commerce for Oceans and Atmosphere to participate in the September 8-9, 2000, commemoration of the 1900 Galveston Storm. Dr. D. James Baker is an honored guest and will provide greeting remarks at the September 8 Centennial Tribute, at which CBS Evening News anchor Dan Rather will deliver the keynote address. Dr. Baker will also participate in the September 9 dedication of the Place of Remembrance Monument at the seawall in Galveston.

Post-Storm Data Acquisition

The OFCM-sponsored Working Group for Natural Disaster Reduction/Post-Storm Data Acquisition coordinated efforts to examine the devastation that resulted from the tornado outbreak that occurred in southwest Georgia in mid-February 2000. Aerial photography support was provided by the Air Force's Civil Air Patrol. The support provided by the Civil Air Patrol, which was negotiated by the working group and documented in a memorandum of understanding, has proven to be both timely and very cost effective.

WEATHER INFORMATION FOR SURFACE TRANSPORTATION (WIST)

The OFCM and United States Department of Transportation - Federal Highway Administration (USDOT-FHWA) co-sponsored "*Symposium on Weather Information for Surface Transportation: Delivering Improved Safety and Efficiency for Tomorrow*" was held November 30 - December 2, 1999, at the Holiday Inn, Silver Spring, Maryland. This first event of its kind was attended by more than 120 individuals, an unprecedented cross-section of the transportation and weather communities (federal government, states and cities, urban and rural transportation agencies, professional and trade organizations, and government and commercial weather service providers). Keynote speakers were Dr. Stephen Van Beek, Associate Deputy Secretary of Transportation, and Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere and FCMSSR Chairman. The goal of the symposium was to establish the national needs and

requirements for weather information associated with decision-making actions involving surface transportation. Significant progress was made towards this goal, and an initial draft of a requirements document will be completed Fall 2000. A second WIST Symposium is planned for December 4-6, 2000, in Rockville, Maryland. The second WIST Symposium will focus on (a) refinement of WIST requirements, (b) identifying "who can do what today," and (c) initial discussions on a National Weather Information System for Surface Transportation. In addition to previous attendees, OFCM anticipates increased attendance from government and commercial weather service providers, state and municipal DOTs and transit authorities, and other interested parties within the Intelligent Transportation Society (ITS) community.

AVIATION WEATHER FORUM

The OFCM and United States Department of Transportation - Federal Aviation Administration (USDOT-FAA) co-sponsored user forum "*Aviation Weather: Opportunities for Implementation*" was held July 25-26, 2000, at the Bethesda Ramada Hotel and Conference Center, Bethesda, Maryland. The forum brought together key government agency representatives, as well as a cross section of professionals representing commercial, business, and general aviation; the forum dynamics clearly demonstrated unanimous interest in aviation safety, efficiency and effectiveness for the benefit of all. The forum focused on five major areas common to National Aviation Weather Initiatives. They are: product development; product dissemination; cockpit multifunctional displays; training; and decision support systems. Reports were given on work being done in eight service areas identified by the aviation community, including: ceiling and visibility; convective hazards; en route winds and temperatures; ground de-icing and anti-icing; in-flight icing; terminal wind and temperature hazards; turbulence; and volcanic ash and other airborne hazardous materials. Keynote speakers were Mr. Peter H. Challan, Deputy Associate Administrator for Air Traffic Services, FAA, and Mr. Scott B. Gudes, Deputy Under Secretary for Oceans and Atmosphere, Department of Commerce. The goal of the forum was to highlight work accomplished, identify opportunities for immediate or near-term implementation, and assess where user and industry efforts are helping government agencies achieve the National Aviation Weather Program objectives.

WORKSHOP ON MULTISCALE ATMOSPHERIC DISPERSION MODELING WITHIN THE FEDERAL COMMUNITY

The OFCM sponsored "*Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community*" was held June 6-8, 2000, at the Town Center Hotel, Silver Spring, Maryland. The workshop was attended by over fifty participants who represented nine federal agencies involved in dispersion modeling. The requirements for dispersion modeling within the federal government are derived from various agency missions including emergency response, national security, public health, and transportation safety that respond to events with both natural and human causes. Such events as volcanic ash, chemical, biological and nuclear releases, pollution, and smoke from forest fires represent potential threats to the health and well being of the population and are of concern to both emergency managers and government officials. The goal of the workshop was to bring users and developers of dispersion models together to improve the coordination in the development and operational use of dispersion models. This workshop provided an opportunity to assess the current state of dispersion modeling and to identify barriers that need to be overcome in order to meet the wide range of requirements.

SPACE WEATHER

Space weather refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems, and can endanger human life or health. Space weather storms can cause disruption of satellites, communications, navigation, and electric power distribution grids. The overarching goal of the National Space Weather Program, which is managed by an OFCM program council, is to achieve an active, synergistic, interagency system to provide timely, accurate, and reliable space weather warnings, observations, specifications, and forecasts within the next ten years. The National Space Weather Program Strategic Plan outlined a strategy to guide the planning and implementation of the National Space Weather Program. During FY 2000 OFCM space weather groups prepared a second edition of the *National Space Weather Program Implementation Plan*. It was developed concurrently with the National Security Space Architect's Space Weather Architecture and describes the linkage to and incorporation of that architecture into the National Space Weather Program. It also builds on the previous Implementation Plan and reports on the significant accomplishments in research, operations, technology transition, education, and outreach. The Plan also updates the program's timelines and offers specific recommendations to carry the program forward.

IMPLEMENTATION OF COORDINATING INFRASTRUCTURE

OFCM completed the restructuring of the interagency coordinating

process which has reduced the number of groups and results in a better fit with agencies' perspectives and 21st Century focus areas and priorities. The Federal and Interdepartmental Committees for Meteorological Services and Supporting Research continue to provide policy and program guidance to OFCM, which will address the most important cross-cutting issues and support those initiatives where the end value has a clear societal benefit. The National Space Weather and National Aviation Weather Program Councils remain the same. The standing committees have become: Environmental Services, Operations and Research Needs; Climate Monitoring and Services; Operational Processing Centers; Integrated Observing Systems; Environmental Information Systems and Communications; and Cooperative Research. Working Groups have been reduced in number and cover broader areas, and Joint Action Groups are established as needed for limited periods of time to focus on specific issues. Implementation included identifying Chairpersons and members for OFCM's groups to get stronger participation from many agencies, identifying important issues, and arranging for meetings of the interagency groups. Terms of References are being finalized. The expanded responsibilities of the office include high pay-off areas such as natural disaster reduction, aviation safety, urban meteorology and air quality, marine and ocean environmental services, weather support to surface transportation, climate services, radio spectrum policy, information dissemination technologies, integrated observing systems, and ensuring a long-term climate record.

NATIONAL HURRICANE CONFERENCE

OFCM worked with the National Weather Service to organize a panel on "*Improving Public Response to Hurricane Warnings*" for the April 17-21, 2000, National Hurricane Conference in New Orleans, Louisiana. The purpose of the panel was to elicit suggestions from the panel members and the conference attendees on how to improve public response. These suggestions will be used to improve current and future hurricane operations. The panel encouraged cross-cutting participation by several conference groups (meteorology, emergency management, universities, media, Red Cross, insurance companies, etc.). Areas covered include societal response/behavioral aspects, communications, education, and public outreach. Recommendations for follow-on work included areas such as societal vulnerability mapping, focusing on education, delivering a frequent and consistent message to the public, assessing what is being done and what is needed to improve public response, working on communications issues, and adopting a standard for communications with the public. Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere, was a keynote speaker for the National Hurricane Conference. OFCM arranged for Dr. Baker to be first on the agenda for the General Session kick-off.

NATIONAL RESEARCH COUNCIL/NATIONAL ACADEMY OF SCIENCES

Joint Meeting of the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) and National Research Council/National Academy of Sciences Board on Atmospheric Sciences and Climate (BASC)

The first joint meeting between FCMSSR and BASC was held October 25, 1999, at the National Academy of Sciences Main Building on Constitution Avenue, Washington, D.C. The meeting was co-chaired by Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere and FCMSSR Chairman, and Dr. Eric J. Baron, Professor at Pennsylvania State University and Co-chair of BASC. The meeting provided an opportunity to strengthen ties between the federal meteorological community, academia, and the private sector. It made clear the need for improvements in weather and climate services, the importance of transitioning research to operations, and the need to do more to capture the socio-economic value of weather, climate, and environmental information services. FCMSSR and BASC attendees agreed that the meeting was very valuable. Actions are being worked on and will be reported at the upcoming November 14, 2000, FCMSSR meeting, which will be attended by the Co-chair and Director of BASC. The August 8-11, 2000, BASC Summer Study on Climate Services at Woods Hole, Massachusetts, was a result of the joint FCMSSR/BASC meeting.

BASC 21st Century Report Recommendation--A Strategy for Atmospheric Information

OFCM is planning a workshop to respond to and address Leadership and Management Recommendation 1 of the BASC report *The Atmospheric Sciences Entering the Twenty-First Century*, which states: "The Federal Coordinator for Meteorological Services and Supporting Research should lead a thorough examination of the issues that arise as the national system for providing atmospheric information becomes more distributed. Key federal organizations, the private sector, academe, and professional organizations should all be represented in such a study and should help develop a strategic plan." Important issues include: What criteria should govern the design of an optimal atmospheric information system? Should the government seek to recover costs of observations from the public by mechanisms

other than taxes? Who is to be responsible for forecasts for critical activities such as agriculture and aviation? Should federal agencies be responsible for supporting research to improve forecasts for such critical activities? What is the appropriate role for academic research, both basic and applied, in such an evolving weather information system, and how should such research be supported so that it remains vigorous and contributes to national goals?

COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

OFCM continued to develop its interactions with the Committee on Environment and Natural Resources (CENR) Subcommittee on Natural Disaster Reduction (SNDR). OFCM senior meteorologist staff participated in meetings of SNDR throughout the year. And OFCM and SNDR will co-sponsor a workshop on Risk Assessment and Cost-Benefit Analysis in late January or early February 2001. Also, regarding risk assessment, an OFCM senior meteorologist helped conduct a panel session on risk assessment for natural disasters at the 25th Annual Hazards Research and Applications Workshop, July 9-12, 2000, in Boulder, Colorado. An OFCM senior meteorologist will also serve on a two day focus group September 28-29, 2000, at FEMA's Emergency Management Institute in Emmitsburg, Maryland, to help develop a classroom based, upper division college course on "Hazards Risk Assessment."

DEPARTMENT OF ENERGY METEOROLOGICAL COORDINATING COUNCIL

OFCM has continued its close liaison with the DOE Meteorological Coordinating Council (DMCC) whose mission is to coordinate meteorological support and atmospheric research to meet internal DOE objectives. OFCM plans to attend the joint meeting of the Subcommittee on Consequence Assessment and Protective Actions (SCAPA), the DMCC, and the Nuclear Utility Meteorological data User Group (NUMUG) in Las Vegas, Nevada, October 16-20, 2000. During the DMCC portion of the meeting, OFCM will brief on OFCM activities, and results and actions from the OFCM sponsored *"Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community"* which was held June 6-8, 2000, in Silver Spring, Maryland.

AMERICAN METEOROLOGICAL SOCIETY AND THE WEATHER CHANNEL FORUM

OFCM participated in the *"Workshop on Policy Issues in Hurricane Preparedness and Response"* developed by the Atmospheric Policy Program of the American Meteorological Society and sponsored by The Weather Channel, June 6-7, 2000, at The National Press Club, Washington, D.C. The workshop considered the following question: What policy changes are needed to produce weather services, media communications, and emergency management decisions that will optimize hurricane preparedness and response? The opening address of the workshop was given by Dr. D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere. An OFCM senior meteorologist briefed the forum on the recent National Hurricane Conference panel on Improving Public Response to Hurricane Warnings to assist the forum's deliberations concerning hurricane response.

AMERICAN METEOROLOGICAL SOCIETY

During FY 2000 OFCM joined eleven leading environmental science and service corporations in supporting undergraduate scholarships in the atmospheric and related oceanic and hydrologic sciences. The scholarships, awarded for the junior and senior years, are designed to encourage outstanding undergraduates to pursue careers in the fields covered by the awards. OFCM plans to continue this support in FY 2001. OFCM also supports American Meteorological Society endeavors by participating in AMS conferences and workshops and other environmental science education and outreach programs.

NATO MEETING

OFCM hosted a meeting of the NATO Military Committee Meteorological Group (MCMG) Working Group for Operations, Plans and Communications (OPC), June 27-30, 2000. MCMG is composed of national representatives and representatives of major NATO Commanders which provides meteorological policy guidance to the Military Committee, the major NATO Commanders, and the NATO nations. OPC addresses planning and operational issues for meteorological support to NATO exercises and operations and develops meteorological communications capabilities and standard procedures for communications and exchanging meteorological data.

PUBLICATIONS AND OFCM'S WEBSITE

The following plans and publications were prepared in hardcopy form and also placed on OFCM's website (*www.ofcm.gov*):

- *The Federal Plan for Meteorological Services and Supporting Research -- Fiscal Year 2000*
- *National Hurricane Operations Plan*

- *The National Space Weather Program: Implementation Plan (2nd Edition)*

- *54th Interdepartmental Hurricane Conference (Minutes)*

- *Proceedings for the Symposium "Weather Information for Surface Transportation: Delivering Improved Safety and Efficiency for Tomorrow"*

- *Proceedings of the "Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community"*

- *Proceedings of the Aviation Weather User Forum "Aviation Weather: Opportunities for Implementation"*

The following documents are planned for publication during FY 2001:

- *National Plan for Post-Storm Data Acquisition*

- *A National Framework for Volcanic Ash Hazards to Aviation*

- *The Federal Plan for Meteorological Services and Supporting Research -- Fiscal Year 2001*

- *National Hurricane Operations Plan*

- *55th Interdepartmental Hurricane Conference (Minutes)*

- *Proceedings for 2nd Symposium on Weather Information for Surface Transportation*

- *Proceedings for Risk Assessment and Cost-Benefit Analysis Workshop*

- *Proceedings for Severe Local Weather Workshop*

- *Proceedings for Workshop on BASC 21st Century Report Recommendation -- A Strategy for Atmospheric Information*

During FY 2000, OFCM continued to make substantial progress on its use of the Internet. In addition to information about the office, OFCM has placed its current publications on its website, and keeps the website current with information regarding workshops and symposia being conducted by the office. OFCM will continue to make information available on the Internet during FY 2001.

APPENDIX B
ACRONYMS AND ABBREVIATIONS

4DWX	Four Dimensional Weather (Army)
AASHTO	American Association of State Highway and Transportation Officials (FHWA)
ABCS	Army Battle Command System (Army)
ABL	Airborne Laser (AF)
AC	Active Component (DOD)
ACARS	ARINC Communication Addressing and Reporting System
ACE	Aviation Combat Element (USMC)
ACP	Atmospheric Chemistry Program (DOE)
ACRIMSAT	Active Cavity Radiometer Irradiance Monitor Satellite (NASA)
ADAS	AWOS/ASOS Data Acquisition System (FAA)
ADEOS	Advanced Earth Observing System (NASA)
AERONET	Aerosol Robotic Network (NASA)
AESS	Allied Environmental Support System (Navy)
AF	Air Force (USAF)
AFB	Air Force Base
AFCCC	Air Force Combat Climatology Center
AFCWC	Air Force Global Combat Weather Center
AFJI	Air Force Joint Instruction
AFRL	Air Force Research Laboratory
AFTAC	Air Force Technical Applications Center
AFW	Air Force Weather
AFWA	Air Force Weather Agency
AFWIN	Air Force Weather Information Network
AHPS	Advanced Hydrologic Prediction System (NOAA/NWS)
AGFS	Aviation Gridded Forecast System (FAA)
AIP	Airport Improvement Program (FAA)
AIRMoN	Atmospheric Integrated Research Monitoring Network (NOAA/OAR)
AIRS	Atmospheric Infrared Sounder (NASA)
AL	Aeronomy Laboratory (NOAA/ERL)
ALC	Adelphi Laboratory Center (Army)
ALDARS	Automated Lightning Detection and Reporting System (FAA)
AMC	Army Matériel Command (Army)
AMDAR	Automatic Meteorological Data and Reporting
AMIS	Automated Meteorological Information System (AF)
AMOS	Automated Meteorological Observing System (Navy)
AMSU	Advanced Microwave Sounding Unit
AMU	Applied Meteorology Unit (NASA)
ANG	Air National Guard
AOC	Aircraft Operations Center (NOAA)
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA/ERL)
AOR	Area of Responsibility (AF)
AOT	Aerosol Optical Thickness
APT	Automatic Picture Transmission
AR	Army Regulation
ARAC	Atmospheric Release Advisory Capability (DOE)
ARCS	Atmospheric Radiation CART Sites (NOAA/OAR)
ARG	Accident Response Group (DOE)
ARGOS	French Satellite Data Collection System
ARINC	Aeronautical Radio Incorporated
ARL	Army Research Laboratory (Army) Air Resources Laboratory (NOAA)
ARM	Atmospheric Radiation Monitoring (DOE)
ARNG	Army National Guard

ARO	Army Research Office
ARS	Agricultural Research Service (USDA)
	Air Traffic System Requirements Service (FAA)
ARSR	Air Route Surveillance Radar (FAA)
ARTCC	Air Route Traffic Control Center (FAA)
ARTYMET	Artillery Meteorological (Army)
ARW	Aviation Weather Directorate (FAA)
ASD	Atmospheric Sciences Division (DOE)
ASDAR	Aircraft to Satellite Data Relay
ASNE	Air and Space Natural Environment (AF)
ASOS	Automated Surface Observing System
ASR	Airport Surveillance Radar (FAA)
ATC	Air Traffic Control (FAA)
ATCCS	Army Tactical Command and Control System
ATDD	Atmospheric Turbulence and Diffusion Division (NOAA/ARL)
ATWIS	Advanced Transportation Weather Information System (FHWA)
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
AVO	Alaskan Volcano Observatory (DOI/USGS)
AWARDS	Agricultural Water Resources Decision Support (DOI/BUREC)
AWC	Aviation Weather Center (NOAA/NCEP)
AWDS	Automated Weather Distribution System (AF)
AWE	Army Warfighting Experiments
AWIPS	Advanced Weather Interactive Processing Systems (NOAA)
AWN	Automated Weather Network (AF)
AWOS	Automated Weather Observing System (FAA)
AWR	Aviation Weather Research (FAA)
AWSS	Aviation Weather Sensor System (FAA)
BASC	Board on Atmospheric Sciences and Climate
BE	Battlefield Environment (Army)
BED	Battlefield Environment Directorate (Army)
BFA	Battlefield Functional Areas (Army)
BLM	Bureau of Land Management (DOI)
BNL	Brookhaven National Laboratory (DOE)
BUFR	Binary Universal Form for the Representation of Meteorological Data
BUREC	Bureau of Reclamation (DOI)
C^2	Command and control (DOD)
C^4I	Command, Control, Communications, Computer and Information (DOD)
CAAM	Computer Assisted Artillery Meteorology (Army)
CALJET	California Land-falling Jets Experiment (NOAA/OAR)
CAMEX	Convective and Moisture Experiment (NASA)
CAP	Civil Air Patrol
CAPARS	Computer-Assisted Protective Action Recommendation System (DOE)
CARDS	Comprehensive Aerological Reference Data Set (NOAA/NCDC)
CARS	Condition Acquisition and Reporting System (FHWA)
CASPER	Computer Aided System For Planning Efficient Routes (FHWA)
CAWIS	Committee for Automated Weather Information Systems (OFCM)
CBNP	Chemical Biological Non-Proliferation Program (DOE)
CBOFS	Chesapeake Bay Oceanographic Forecasting System (NOAA/NOS)
CCM3	Community Climate Model-3
CDA	Command and Data Acquisition
CDAS	Command and Data Acquisition Station
CDFS	Cloud Depiction and Forecast System (AF)
CEASE	Compact Environment Anomaly Sensor (AF)
CECOM	Communications and Electronics Command (Army)
CEMSCS	Central Environmental Satellite Computer System (NOAA/NESDIS)
CENR	Committee on Environment and Natural Resources

CEOS	Committee on Earth Observation Satellites (NOAA/NWS)
CERES	Clouds and Earth's Radiant Energy System (NASA)
CHAMMP	Computer Hardware Advanced Mathematics and Model Physics (DOE)
CIASTA	Cooperative Institute for Atmospheric Studies and Terrestrial Applications (NOAA/OAR)
CIDE	Communications Interfaces and Data Exchange (OFCM)
CINC	Commanders-in-Chief (DOD)
CIRES	Cooperative Institute for Research in Environmental Sciences (NOAA)
CMAQ	Community Multi-scale Air Quality (EPA)
CME	Coronal Mass Ejection (AF)
CMFC	Coordinating METOC Forecast Center (Navy)
COADS	Comprehensive Ocean-Atmosphere Data Set (NOAA/NCDC)
COAMPS	Coupled Oceanographic and Atmospheric Model (Navy)
COARE	Coupled Ocean-Atmosphere Response Experiment
COE	Corps of Engineers (Army)
COMET	Cooperative Program for Operational Meteorology, Education and Training
CONUS	Continental United States
COPC	Committee for Operational Processing Centers (OFCM)
CORMS	Continuous Real-time Monitoring System (NOAA/NOS)
COTS	Commercial Off-the-Shelf
CPC	Climate Prediction Center (NOAA/NCEP)
CRADA	Cooperative Research and Development Agreement
CRN	Climate Reference Network (NOAA)
CRREL	Cold Regions Research and Engineering Laboratory (Army)
CS	Climate Services (OFCM)
CSREES	Cooperative State Research, Education, and Extensive Service (USDA)
CSSM	Cloud Scene Simulation Model (AF)
CTA	Common Table of Allowances (Army)
CTBT	Comprehensive Test Ban Treaty (DOE)
CTWFC	CINC Target Weather Forecast Center (AF)
CWSU	Center Weather Service Unit (FAA)
CWT	Combat Weather Team (AF)
CY	Calendar Year
DAC	Data Assembly Center (NOAA/OAR)
DAMPS	Distributed Atmospheric Modeling Prediction System (Navy)
DCO	Data Collection Office (NOAA/NWS)
DCP	Data Collection Package
DCS	Data Collection System (NOAA/NESDIS)
DISS	Digital Ionospheric Sounding System (AF)
DMCC	DOE Meteorological Coordinating Council
DMSO	Defense Modeling and Simulation Office (AF)
DMSP	Defense Meteorological Satellite Program (AF)
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOMSAT	Domestic Communications Satellite
DOS	Department of State
DOT	Department of Transportation
DRA	Desert Rock Meteorological Observatory (DOE)
DRGS	Direct readout ground stations (DOI)
DURIP	Defense University Research Instrumentation Program (Army)
DRWP	Doppler Radar Wind Profiler (NASA)
DTC	Developmental Test Command (Army)
DTSS	Digital Topographic Support System (Army)

DUAT	Direct User Access Terminal (FAA)
DWSW	Deployable Weather Satellite Workstation (Army)
ECDIS	Electronic Chart Display Information System (NOAA/NOS)
ECMWF	European Centre for Medium-Range Weather Forecasting
EDAS	Eta Data Assimilation System (NOAA/NESDIS)
EDIS	Environmental Data and Information Service (NOAA)
EMC	Environmental Modeling Center (NOAA/NCEP)
ENSO	El Niño-Southern Oscillation
EO	electro-optical Earth Observation (NASA)
EOC	Emergency Operations Center
EOS	Earth Observing System (NASA)
EOSDIS	EOS Data and Information System (NASA)
EPA	Environmental Protection Agency
EPD	Environmental Protection Division (DOE)
E-PIREPS	Electronic Pilot Reports (FAA)
EPSCoR	Experimental Program to Stimulate Competitivee Research (DOD)
ER	Eastern Range (NASA)
ERBS	Earth Radiation Budget Satellite (NASA)
ERC	Extended Research Checkout
ERDAS	Eastern Range Dispersion Assessment System (NASA)
ERDC	Engineering Research and Development Center (Army)
ERL	Environmental Research Laboratories (NOAA)
ESD/IPC	Environmental Satellite Distribution/Interactive Processing Center (NOAA/NESDIS)
ESE	Earth Science Enterprise (NASA)
ESS	Environmental Sensor Station (FHWA)
ESIP	Earth Science Information Partners (NASA)
ESSP	Earth System Science Pathfinders (NASA)
ETL	Environmental Technology Laboratory (NOAA/ERL)
ETTP	East Tennessee Technology Park (DOE)
ETM+	Enhanced Thematic Mapper Plus (NASA)
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUSA	Eighth U.S. Army
EUV	Extreme Ultraviolet
FAA	Federal Aviation Administration
FALOP	Forward Areal Limited Observing Program (AF)
FAS	Foreign Agricultural Service (USDA)
FCCC	Framework Convention on Climate Change (DOS)
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FDD	First Digitized Division (Army)
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRESTORM	Federation of Intelligence, Reconnaissance, Surveillance, and Targeting Operations and Research Models (Army)
FIRETEC	Fire Behavior Model (DOE)
FLENUMMETOCCEN	Fleet Meteorology and Oceanography Center, Monterey, California
FMF	Fleet Marine Force
FMH	Federal Meteorological Handbook (OFCM)
FNMOC	Fleet Numerical Meteorology and Oceanography Center (Navy)
FOA	Field operating agency (AF)
FOC	Future Operational Capability (Army)
FORSCOM	U.S. Army Forces Command
FOSDIC	Film Optical Sensing Device for Input to Computer
FOV	Field of vision
FRD	Field Research Division (NOAA/ARL)

FRERP	Federal Radiological Emergency Response Plan (DOE)
FRMAC	Federal Radiological Monitoring and Assessment Center (DOE)
FRRS	Federal Records Retention System
FS-21	Forecasting System 21st Century
FS	Forest Service (USDA)
FSA	Farm Services Agency (USDA)
FSL	Forecast Systems Laboratory (NOAA/ERL)
FTE	Full-time Equivalent
FTP	File Transfer Protocol
FU	Forecast Unit
FY	fiscal year
G-IV	Gulfstream IV (NOAA)
GAC	Global Area Coverage
GAPP	GEWEX Applications Prediction Program (DOI/BUREC)
GAO	General Accounting Office
GCCR	Global Climate Change Research (DOE)
GCCS	Global Command and Control System (DOD)
GCIP	GEWEX Continental-scale International Project (DOI)
GCM	Global Climate Models (DOE)
GCOS	Global Climate Observing System (WWP)
GCPS	Global Climate Perspectives System
GCRP	Global Change Research Program
GEOSAR	Geostationary Earth Orbit Search and Rescue (NOAA/NESDIS)
GEWEX	Global Energy and Water-Balance Experiment
GFDL	Geophysical Fluid Dynamics Laboratory (NOAA/ERL)
GHCN	Global Historical Climatology Network
G-IPPA	Government-Industry Project Performance Agreement (FAA)
GIN	Geomagnetic Information Nodes (DOI)
GIS	Geographic Information System
GLD	Global Lagrangian Drifters (NOAA/OAR)
GLONASS	Global Navigation Satellite System (NOAA/NESDIS)
GMS	Geostationary Meteorological Satellite (Japan)
GMSRA	GOES Multi-Spectral Rainfall Algorithms (NESDIS)
GOES	Geostationary Operational Environmental Satellite (NOAA)
GOOS	Global Ocean Observing System
GOS	Global Observing System (WWP)
GOSSP	Global Observing Systems Space Panel
GPCP	Global Precipitation Climatology Program
GPS	Global Positioning System
GPS/MET	GPS for Meteorology
GRACE	Gravity Recovery and Climate Experiment (NASA)
GRIB	Gridded Binary (FM 92-X Ext.)
GSFC	Goddard Space Flight Center (NASA)
GSN	GCOS Surface Network (WWP)
GTS	Global Telecommunications System (WWP)
GTSPP	Global Temperature-Salinity Pilot Project
GTWAPS	Global Theater Weather Analysis and Prediction System (AF)
GUAN	GCOS Upper Air Network (WWP)
HaL	Hurricanes at Landfall (NOAA.OAR)
HCRS	Highway Closure and Restriction System (FHWA)
HELSTF	High Energy Laser System Test Facility (Army)
HF	High frequency (AF)
HFRB	High frequency radio broadcast (DOD)
HIGRAD	High Resolution and Strong Gradient
HIRS/3	High Resolution Infrared Radiation Sounder (NOAA/NESDIS)

HMSC	Hazardous Materials Spill Center (DOE)
HMMWV	High Mobility Multi-purpose Wheeled Vehicle (Army)
HPC	Hydrometeorological Prediction Center (NOAA/NCEP)
HPCC	High Performance Computing and Communications
HRD	Hurricane Research Division (NOAA/ERL)
HRPT	High Resolution Picture Transmission (NOAA/NESDIS)
HUD	Head-up display (NASA)
IAMS	Initial Attack Management System (DOI)
ICAO	International Civil Aviation Organization
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
ICSU	International Council of Scientific Unions
IDCS	International Data Collection System (WWP)
IEN	Information Exchange Network (FHWA)
IEW	Intelligence and Electronic Warfare (Army)
IFFA	Interactive Flash Flood Analyzer (NOAA/NESDIS)
IGBP	International Geosphere Biosphere Programme (WWP)
IHC	Interdepartmental Hurricane Conference (OFCM)
IIP	International Ice Patrol (USCG)
IMDES	Interdepartmental Meteorological Data Exchange System
IMETS	Integrated Meteorological System (Army)
	Incident Meteorologists (NOAA/NWS)
IMEX	Inner Magnetosphere Explorer (NASA)
IMOSS	Interim Mobile Oceanography Support System (Navy)
IMS	Ionospheric Measuring System (AF)
INEEL	Idaho National Engineering and Environmental Laboratory (DOE)
INSAT	India's Indian National Satellite (WWP)
IPCC	Intergovernmental Panel on Climate Change (WWP/DOS)
IPO	Integrated Program Office
IR	infrared
IRRIS	Intelligent Road and Rail Information System (FHWA)
IRTSS	Infrared Target Scene Simulation Software (AF)
ISCCP	International Satellite Cloud Climatology Program
ISIS	Integrated Solar Irradiance Study (NOAA/OAR)
ISPM	Interplanetary Shock Propagation Models (AF)
ISOON	Improved Solar Optical Observing Network (AF)
ITCZ	Inter-tropical convergence zone
ITS	Intelligent Transportation System (FHWA)
ITS-JPO	ITS Joint Program Office FHWA)
ITWS	Integrated Terminal Weather System (FAA)
IWEDA	Integrated Weather Effects Decision Aid (Army)
IWRS	Improved Weather Reconnaissance System
IWRPC	Improved Weather Reconnaissance System Program Council
J-TRWS	Joint TESS Remote Workstation (Navy)
JAG	Joint Action Group
JASL	Joint Archive for Sea Level
JAWF	Joint Agricultural Weather Facility (USDA)
JGOFS	Joint Global Ocean Flux Study
JMTK	Joint Mapping Took Kit (Army)
JMV	Joint METOC Viewer (Navy)
JPL	Joint Propulsion Laboratory (NASA)
JSC	Johnson Space Center (NASA)
JTWC	Joint Typhoon Warning Center (AF/Navy)
KM	Kilometer
KMR	Kwajalein Missile Range (Army)

KSC	Kennedy Space Center
LAC	Local Area Coverage
LAN	local area network
LANL	Los Almos National Library (DOE)
LAPS	Local Analysis and Prediction System (NOAA/FSL)
LLNL	Lawrence Livermore National Laboratory (DOE)
LLWAS	Low Level Wind Shear Alert System (FAA)
LLWAS-RS	LLWAS-Relocation/Sustainment (FAA)
LRGS	local readout ground stations (DOI)
MACOM	Major Army Command
MAGTF	Marine Air Ground Task Force
MAIS	Military Aircrew Information System (AF)
MAJCOM	Major Command (AF)
MB	Millibars
MC	Meteorological Codes
MDCRS	Meteorological Data Communications and Reporting System (WWP)
MDS	Meteorological Distribution System (Army)
MEPED	Medium Energy Proton and Electron Detector (NOAA/NESDIS)
MES	Marine Environmental Services (OFCM)
MET	Mobile Environmental Teams (Navy) Meteorological Teams (Army)
METMF(R)	Meteorological Mobile Facility (Replacement) (Navy)
METOC	Meteorological and Oceanographic (DOD)
MIMS	Multimedia Integrated Modeling System (EPA)
MISR	Multi-Angle Imaging Spectrometer (NASA)
MIST	Meteorological Information Standard Terminal (AF)
MM5	Mesoscale Meteorological Model-Version 5.0 (AF)
MME	Mobile Meteorological Equipment (OFCM)
MMS	Meteorological Measuring System (Army) Mineral Management Service (DOI)
MMS-P	Meteorological Measuring System-Profiler (Army)
MOA	Memorandum of Agreement
MOBY	Marine Optical Buoy (NOAA/NESDIS)
MOCE	Marine Optical Characterization Experiment (NOAA/NESDIA)
MODIS	Moderate Resolution Imaging Spectrometer (NASA)
MOS	Manual Observing System (AF)
MPC	Marine Prediction Center (NOAA/NCEP)
MS	Monitoring the Stratosphere (OFCM)
MSCP	Meteorological and Climate Services Project (DOE)
MSEA	Modeling and Simulatin Executive Agent (AF)
MSFC	Marshall Space Flight Center (NASA)
MSL	Mean sea level
MSM	Magnetospheric Specification Model (AF)
MST	Meteorological Support Teams (USMC)
MSU	Microwave Sounding Unit (NOAA/NESDIS)
MTN	Main Telecommunications Network (WWP)
MTPE	Mission to Planet Earth (NASA)
MWSS	Marine Wing Support Squadron
NADIN	National Airspace Data Interchange Network (FAA)
NAMIS	NATO Automated Meteorological Information System (AF)
NAPP	National Aerial Photography Program (USDA)
NAOS	North American Atmospheric Observing System (NOAA)
NARAC	National Atmospheric Release Advisory Center (DOE)
NARSTO	North American Research Strategy on Tropospheric Ozone (EPA)

NAS	National Airspace System (FAA)
	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service (USDA)
NATCOM	National Communications Center (FAA)
NAVICECEN	Naval Ice Center
NAVOCEANO	Naval Oceanographic Office
NAVLANTMETOCCEN	Naval Atlantic Meteorology and Oceanography Center, Norfolk, Virginia
NAVMETOCCOM	Naval Meteorology and Oceanography Command
NAVPACMETOCCEN	Naval Pacific Meteorology and Oceanography Center, Pearl Harbor, Hawaii
NAWPC	National Aviation Weather Program Council (OFCM)
NBC	Nuclear, Biological, and Chemical (DOD)
NC	NOAA Corps Operations
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center (NOAA/NESDIS)
NCEP	National Center for Environmental Prediction (NOAA/NWS)
NCO	NCEP Central Operations (NOAA/NCEP)
	Non-commissioned officer (DOD)
NDBC	National Data Buoy Center (NOAA/NWS)
NDI	non-developmental item
NDOP	National Digital Orthoquad Program (USDA)
NDRI	Natural Disaster Reduction Initiative (NOAA)
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NESHAP	*National Emission Standards for Hazardous Air Pollutants* (DOE)
NESS	National Environmental Satellite Service (NOAA)
NEST	Nuclear Emergency Search Team (DOE)
NEXRAD	Next Generation Weather Radar (WSR-88D)
NFIP	National Flood INsurance Program (FEMA)
NFDRS	National Fire Danger Rating System (DOI/BLM)
NGDC	National Geophysical Data Center (NOAA/NESDIS)
NGIC	National Geomagnetic Information Center (DOI)
NGRVR	New Generation Runway Visual Range (FAA)
NHC	National Hurricane Center (NOAA/NWS)
NHOP	National Hurricane Operations Plan (OFCM)
NIC	National Ice Center (DOT/USCG)
NIFC	National Interagency Fire Center (DOI)
NIPRNET	Non-secure Internet Protocol Network (AF)
NIST	National Institute of Standards and Technology (DOC)
NITES	Naval Integrated Tactical Environmental Subsystem
NLDN	National Lightning Detection Network (FAA)
NMC	National Meteorological Center(s) (WWP)
NMOC	Naval Meteorology and Oceanography Command
NMP	New Mellenium Program (NASA)
NMTN	National Telecommunications Network (WWP)
NNDC	NOAA National Data Center (NOAA/NESDIS)
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center (NOAA/NESDIS)
NODDS	Naval Oceanographic Data Distribution System
NOGAPS	Navy Operational Global Atmospheric Prediction System
NOS	National Ocean Service (NOAA)
NOTAMS	Notices to Airman (FAA)
NOWS	NVG Operations Weather Software (AF)
NPN	NOAA Profiler Network
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Program (NASA)
NPS	National Park Service (DOI)

NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service (USDA)
NRL	Naval Research Laboratory
NRO	National Reconnaissance Office (AF)
NSCAT	NASA Scatterometer (NASA)
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center (NOAA)
NSSL	National Severe Storms Laboratory (NOAA)
NSTC	National Science and Technology Council
NSWP	National Space Weather Program (OFCM)
N-TFS	New Tactical Forecast System (AF)
NTS	Nevada Test Site (DOE)
NTSB	National Transportation Safety Board
NV	Nevada Operations Office (DOE)
NVG	night vision goggle (DOD)
NWLON	National Water-Level Observation Network (NOAA/NOS)
NWP	Numerical Weather Predication
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research (NOAA)
OASIS	Operational and Supportability Implementation System (FAA)
OCAP	Operating Consortium of ASDAR Participants (WWP)
ODCSINT	Office of the Deputy Chief of Staff for Intelligence (Army)
ODCSOPS	Office of the Deputy Chief of Staff for Operations (Army)
OES	Office of Earth Sciences (NASA)
OFCM	Office of the Federal Coordinator for Meteorology
OGP	Office of Global Programs (NOAA)
OMB	Office of Management and Budget
ONR	Office of Naval Research
OPAREA	Fleet Operational Area (Navy)
OPARS	Optimum Path Aircraft Routing System (Navy)
OPS-II	Operational Weather Squadron Production System, Phase 2
OP-SEND	Operationalized Space Environment Network Display (AF)
OR&F	Operations, Research, and Facilities (NOAA/NWS)
ORA	Office of Research and Applications (NOAA/NESDIS)
ORAU	Oak Ridge Associated Universities (DOE)
ORD	Operational Requirements Documents (Navy)
ORISE	Oak Ridge Institute for Science and Education (DOE)
ORR	Oak Ridge Reservation (DOE)
ORNL	Oak Ridge National Laboratory (DOE)
ORO	Oak Ridge Operations (DOE)
OS-21	Observing System-21st Century (AF)
OSDPD	Office of Satellite Data Processing and Distribution (NOAA/NESDIS)
OSEI	Operational Significant Event Imagery (NOAA/NESDIS)
OSF	Operational Support Facility (NOAA)
OSO	Office of Satellite Operations (NOAA/NESDIS)
OSTEP	Ocean Systems Test and Evaluation Program (NOAA/NOS)
OSTP	Office of Sciencey and Technology Policy
OTH	Over the horizon (NOAA/OAR)
OTW	Owning the Weather (Army)
OTSR	Optimum Track Ship Routing (Navy)
OWS	Operational Weather Squadron (AF)
OWSE	Operational World Weather Watch Systems Evaluation (WWP)
PAC	Procurement, Acquisition, and Construction (NOAA/NWS)
PACS	Polar Acquisition and Control Subsystem (NOAA/NESDIS)
PASOS	Portable Automated Observing System (AF)

PC	Program Council (OFCM)
PCMDI	Program for Climate Model Diagnosis and Intercomparison (DOE)
PD	Project Director (Army)
PECAD	Production Estimates and Corp Assessment Division (USDA)
PIBAL	Pilot Balloon
PIRATA	Pilot Research Moored Array in the Tropical Atlantic (NOAA/OAR)
PIREP	Pilot Report
PMEL	Pacific Marine Environmental Laboratory (NOAA/ERL)
PNNL	Pacific Northwest National Laboratories (DOE)
POES	Polar-Orbiting Operational Environmental Satellite (NOAA)
POP	Parallel Ocean Program (DOE)
POPS	Primary Oceanographic Prediction System (Navy)
PORTS	Physical Oceanographic Real-Time System (NOAA/NOS)
PRISM	Parameterized Real-time Ionospheric and Specification Model (AF)
PSDA	Post-Storm Data Acquisition (OFCM)
PSR	Polarimetric Scanning Radiometer (NOAA/OAR)
PUP	Principal User Processor
QPF	Quantitative Precipitation Forecast (NOAA/NCEP)
R&D	Research and Development
RAFC	Regional Area Forecast Center (WWP)
RAMS	Regional Atmopsheric Modeling System
RAMSDIS	RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (NOAA/NESDIS)
RAP	Radiological Assistance Program (DOE)
RARC	Regional Atmospheric Response Center (DOE)
RASS	Radio Acoustic Sounding System (NOAA/OAR)
RAWS	Remote Automatic Weather Station (USDA/DOI)
RC	Reserve Component (DOD)
RDTE	Research and Development, Test and Evaluation (Army)
REEPER	Relativistic Electorn and Energetic Proton Experiment (AF)
RFETS	Rocky Flats Environmental Technology Site (DOE)
RFC	River Forecast Center (NOAA/NWS)
RMTN	Regional Telecommunications Network (WWP)
RPC	Rapid Prototype Center (NOAA/SEC)
RSA	Range Standardization and Automation (NASA)
RSMC	Regional/Specialized Meteorological Centers (WWP)
RTH	Regional Telecommunications Hub (WWP)
RUC	Rapid Update Cycle (NOAA)
RVR	Runway Visual Range (FAA)
RWIS	Road Weather Information System (FHWA)
S2	Intelligence Section (Army)
SAA	Satellite Active Archive
	Snow Accumulation Algorithm (DOI/BLM)
SAR	Synthetic Aperture Radar (NOAA/NESDIS)
SARSAT	Search and Rescue Satellite Aided Tracking
SBIR	Small Business Innovative Research Program (DOD)
SBUV	Solar Backscatter Ultra-violet Instrument (NOAA/NESDIS)
SCINDA	Scintillation Network Decision Aid (AF)
SDHS	Satellite Data Handling System (AF)
SEC	Space Environmental Center (NOAA/NCEP)
SEM	Space Environment Monitor (NOAA)
SEMSIM	Southeastern Michigan Snow and Ice Management (FHWA)
SFMR	Stepped Frequency Microwave Radiometer
SHEBA	Surface Heat Budget of the Arctic Ocean (DOE)

SHRP	Stragetic Highway Research Program (FHWA)
SMEI	Solar Mass Ejection Imager (AF)
SMDC	Space and Missile Defense Command (DOE)
SMOOS	Shipboard Meteorological and Oceanographic Observing Sensor (Navy)
SNDR	Subcommittee on Natural Disaster Reduction
SNL	Sandia National Laboratory (DOE)
SNOTEL	Snow Telemetry (USDA)
SOCC	Satellite Operations Control Center (NOAA/NESDIS)
SODAR	Sound Detection and Ranging (DOE)
SOF	Special Operations Forces (Army)
SOLAS	Safety of Life at Sea (NOAA/NCEP)
SORD	Special Operations and Research Division (NOAA/ARL)
SPAWARSYSCOM	Space and Naval Warfare Systems Command
SPC	Storm Prediction Center (NOAA/NCEP)
SR	Savannah River (DOE)
SRBL	Solar Radio Burst Locator (AF)
SRS	Savannah River Site (DOE)
SRTC	Savannah River Technology Center (DOE)
SST	Sea surface temperature
SSU	Stratospheric Sounding Unit (NOAA)
STIWG	Satellite Telemetry Interagency Working Group (OFCM)
STOA	Shock Time of Arrival (AF)
STP	Solar-Terrestrial Physics
STT	Small Tactical Terminal (AF)
SURFRAD	Surface Radiation (DOE)
SWAFS	Space Weather Analysis and Forecasting System (AF)
SWE	Snow Water Equivalent (DOI/BUREC)
SWIM	Solar Wind Interplanetary Measurements (AF)
SWO	Staff weather officer (AF)
SWXS	Space Weather Squadron (AF)
SXI	Solar X-Ray Imager (AF)
T2	Technology transfer
TAF	Aerodrome Forecast
TAO	Tropical Atmosphere Ocean
TACMET-MOD	Tactical Meteorological Observing System Modification (AF)
TACWX	Tactical weather (DOD)
TAWS	Tactical Acquisition Weather Software (AF)
TDA	Tactical Decision Aid (Army)
TDWR	Terminal Doppler Weather Radar (FAA)
TEA-21	Transportation Equity Act for the 21st Century (FHWA)
TEC	Topographic Engineering Center (Army)
TED	Total Electron Detector (NOAA/NESDIS)
TESS	Tactical Environmental Support System (Navy)
TF	Terminal Forecast
TFF	Task Force Falcon (Army)
TFS	Tactical Forecast System (AF)
TFU	Theater Forecast Unit (AF)
TIROS	Television Infrared Observation Satellite (NOAA/NESDIS)
TMI	TRMM Microwave Imager (NASA)
TOC	Tactical Operations Center (Army)
TOE	Table of Organization and Equipment (Army)
TOFS	Tactical Observing and Forecasting System (AF)
TOGA	Tropical Ocean and Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer (NASA)
TOVS	TIROS N Operational Vertical Sounder (NOAA/NESDIS)
TPC	Tropical Prediction Center (NOAA/NCEP)

TPW	Total Precipitable Water (NOAA/NESDIS)
TRACON	Terminal Radar Approach Control (FAA)
TRADOC	Training and Doctrine Command (Army)
TRMM	Tropical Rainfall Measuring Mission (NASA)
TUAN	Tactical Unmanned Aerial Vehicle (Army)
TWIP	Terminal Weather Information for Pilots (FAA)
TWP	Tropical Western Pacific (DOE)
TWR	Tactical Weather Radar (AF)
UARS	Upper Atmosphere Research Satellite (NASA)
UCAR	University Corporation for Atmospheric Research
UN	United Nations
UNEP	United Nations Environment Program (WWP/DOS)
USA	U.S. Army
USAES	U.S. Army Engineer School
USAF	U.S. Air Force
USAFAS	U.S. Army Field Artillery School
USAIC&FH	U.S. Army Intelligence Center & Fort Huachuca
USAKA	U.S. Army Kwajalein Atoll
USAR	U.S. Army Reserve
USAREUR	U.S. Army Europe
USARIEM	U.S. Army Research Institute of Environmental Medicine
USARPAC	U.S. Army Pacific
USASMDC	U.S. Army Space and Missile Defense Command
USASOC	U.S. Army Special Operations Command
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
USHCN	U.S. Historical Climatology Network
USIABP	U.S. Interagency Arctic Buoy Program (NOAA/NESDIS)
USMC	U.S. Marine Corps
USMCC	U.S. SARSAT Mission Control Center (NOAA/NESDIS)
USN	U.S. Navy
USWRP	U.S. Weather Research Program
UTC	Universal Time Coordinated (Zulu)
UV	Ultra-violet
VA	Volcanic Ash
VAS	VISSR Atmospheric Sounder
VCL	Vegetation Canopy LIDAR (NASA)
VCP	Voluntary Cooperation Program
VIN	Vegetative Index Number (USDA)
VIRS	Visible and Infrared Scanner (NASA)
VISSR	Visible and Infrared Spin Scan Radiometer
VOS	Voluntary Observing Ship (WWP)
VTS	Vessel Traffic System (NOAA/NOS)
WAFC	World Area Forecast Center (WWP)
WAFS	World Area Forecast System (WWP)
WAM	Wave model (Navy)
WAMPS	Weather Automated Mission Planning Software
WAOB	World Agricultural Outlook Board (USDA)
WARP	Weather and Radar Processor (FAA)
WETM	Weather Team (DOD)
WFAS	Wildland Fire Assessment System (DOI)
WFMIS	Wildland Fire Management Information Site (DOI)
WFO	Weather Forecast Office (NOAA/NWS)
WG	Working Group

WGCV	Working Group on Calibration and Validation (NOAA/NESDIS)
WIDA	Weather Impact Decision Aids (AF)
WINDS	Weather Information and Display System (DOE)
WIPP	Waste Isolation Pilot Plant (DOE)
WIST	Weather Information for Surface Transportation (FHWA)
WMC	World Meteorological Center(s) (WWP)
WMO	World Meteorological Organization
WMSCR	Weather Message Switching Center-Replacement (FAA)
WOCE	World Ocean Circulation Experiment
WPDN	Wind Profile Demonstration Network (NOAA)
WRD	Water Resources Division (DOI/USGS)
WRF	Weather Research and Forecast (NOAA/OAR)
WSP	Weather Systems Processor (FAA)
WSR-88D	Weather Surveillance Radar-1988 Doppler (NEXRAD)
WSSRAP	Weldon Springs Site Remdcial Action Project (DOE)
WST	Weather Support Team (Army)
WSU	Weather Support Unit (AF)
WTU	Weather Technology Unit (AF)
WWP	World Weather Program
WWW	World Weather Watch (WMO)
	World wide web
XOW	Director of Weather (AF)

APPENDIX C
PREVIOUS FEATURE ARTICLES

1999	FY 2000	Natural Disaster Reduction--Reducing the Impacts of Natural Hazards	OFCM Staff in collaboration with Dr. William Hooke, OAR, and Ms. Keli Tarp, NOAA Public Affairs
1998	FY 1999	Aviation Weather: Taking A Leadership Role	FAA's Aviation Weather Policy Division (ARW-100) Staff
1997	FY 1998	Owning The Weather--An Army Force Multiplier	Mr. Richard J. Szymber, Army
1996	FY 1997	Space Weather - A New Challenge for Meteorologists	Col Jud Stailey, USAF
1995	FY 1996	The Role of Federal Agencies in International Aviation Meteorology	Mr. Blaine K. Tsugawa, OFCM
1994	FY 1995	Data Continuity in the Climatological Record	Dr. Nathaniel B. Guttman, NCDC Mr. Andrew H. Horvitz, NWS Mr. Arthur L. Booth, NOAA-EOSDIS
1993	FY 1994	Training and Professional Development in the Modernized Weather Services	Mr. Eli Jacks, NWS Mr. LeRoy Spayd, NWS
1992	FY 1993	Mesoscale Meteorology	Mr. Floyd F. Hauth, OFCM
1991	FY 1992	Some Recent Developments in Lightning Mapping Systems	Dr. Donald R. MacGorman, NOAA Dr. Frederick R. Mosher, NOAA Ms. Jan S. Lewis, NOAA
1990	FY 1991	The Next Generation Weather Radar - A System for Locating and Tracking Severe Weather	Mr. E. Don Sarreals, NEXRAD JSPO
1989	FY 1990	Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service	Verbatim reproduction of a plan required by Congress and submitted by DOC and OMB
1988	FY 1989	Supercomputers for Meteorological Services and Supporting Research	(Source or author unknown)

APPENDIX D

WORLD WEATHER PROGRAM

The Department of Commerce (DOC) was designated by the President, following Senate Concurrent Resolution 67 (1968), to be the lead agency for coordinating United States participation in the World Weather Program (WWP). Until 1983, DOC published a separate report on WWP Plans. Beginning with the 1983 edition of the *Federal Plan for Meteorological Services and Supporting Research*, a section on the WWP has been included, obviating the need for a separate report. The last segment of this narrative includes information on bilateral and regional international cooperative activities which are not under the WWP.

GOALS AND ORGANIZATION

The WWP goals to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and climatic change. The ability of the United States and other nations to use their existing scientific capability to understand the climate and to increase their weather predicting skills is limited by the lack of global weather data. Available weather data are inadequately observed over a significant portion of the Earth's surface, especially over isolated areas including the oceans.

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

The WMO, with 185 Members, is a specialized agency created by the UN to facilitate international cooperation in the fields of meteorology and hydrology. The WMO responded to the UN request with the concept of the World Weather Watch (WWW), an operational system to bring the global atmosphere under improved surveillance and to provide for the rapid collection and exchange of weather data as well as for the dissemination of weather products from centralized processing centers.

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

The responsibilities of United States federal agencies in the WWP are as follows:

- Department of Commerce (DOC). Represents the United States at WMO and, through the National Oceanic and Atmospheric Administration (NOAA), provides the focal point to coordinate our Nation's efforts in these international programs, implements those service improvements in the existing international weather system for which the United States accepts responsibility, and develops new technology.
- Department of State (DOS). Maintains relations with developing nations and, through NOAA and the WMO, assists developing nations in improving their national weather services. DOS also develops appropriate multilateral and bilateral arrangements to further international participation.
- National Science Foundation (NSF). Stimulates and supports basic research by non-government scientists on atmospheric and ocean circulations and modeling. It also promotes the education and training of atmospheric and ocean scientists at universities.
- Department of Defense (DOD). Although the mission of DOD weather services is basically internal, the nature of DOD's operations is global. As such, the observation, telecommunications, and data-processing programs of the military weather services provide significant indirect support to the WWW through DOD's interface with NOAA's National Weather Service (NWS). Information from the research and development activities of these services is exchanged routinely with other similar national agencies and is often presented at national forums.

- Department of Transportation (DOT). Through the United States Coast Guard, provides personnel to support NOAA's National Data Buoy Center (NDBC) in developing, operating, and evaluating data buoy systems. Coast Guard cutters and aircraft provide operational support to deploy, service, and retrieve buoys built for test or operational purposes. DOT's observation and telecommunications programs also provide significant indirect support to the WWW through DOT's interaction with the NWS.
- National Aeronautics and Space Administration (NASA). Performs research and develops aerospace technology required for an effective global weather system.

THE WORLD WEATHER WATCH

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

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

Global Observing System

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

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

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

Presently, operational meteorological satellites in polar orbits are operated by Russia (the METEOR-3 series) and the United States. The United States operates the civilian NOAA Polar-orbiting Operational Environmental Satellite (POES) series along with the Defense Meteorological Satellite Program (DMSP) series of polar-orbiting spacecraft. NOAA currently launches satellites, alternately, into afternoon and morning orbits to maintain an uninterrupted stream of global data. The current operational NOAA polar-orbiting satellites are NOAA-14 (launched in an afternoon orbit in December 1994) and NOAA-12 (launched in a morning orbit in May 1991). The current operational DMSP polar-orbiting satellites are F-12 (launched in August 1994), F-13 (launched in March 1995), and F-14 (launched in April 1997).

Operational geostationary weather satellites are currently operated by Japan, China, India, Russia, the United States, and the European Operational Satellite Consortium (EUMETSAT). Japan's Geostationary Meteorological Satellite (GMS) is positioned at 140°E, India's Indian National Satellite (INSAT) is at 74°E, Russia's GOMS/Elektro #1 satellite is at 76°E (operational since June 1996), and EUMETSAT's METEOSAT is at 0°. The United States normally operates two Geostationary Operational Environmental Satellites (GOES)--one at 75°W and the other at 135°W. GOES-8, launched in April 1994, is operational at 75°W and GOES-9, launched in May 1995, is operational at 135°W. The China-GOES FY2 was launched June 10, 1997.

To help ensure data continuity from geostationary orbit, NOAA has signed a long-term mutual back-up agreement with EUMETSAT. The successful launch of GOES-10 now gives the United States an on-orbit spare capability reducing the impact when GOES-8 or GOES-9 fails.

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

century. This complements longstanding plans by NOAA and the meteorological operational satellites. In parallel with the United States converged system, EUMETSAT will assume the responsibility of the "morning" polar orbiter with its new METOP series.

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

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

Over the last few years, several systems intended to improve the operation of the GOS have continued to undergo development and deployment. Among these systems is the family of automated aircraft reporting systems known as the Automated Meteorological-logical Data and Reporting (AMDAR) systems. This family of systems includes the Aircraft to Satellite Data Relay (ASDAR) System and the ARINC Communications Addressing and Reporting System (ACARS). ARINC is Aeronautical Radio Incorporated--a wholly owned subsidiary of the airlines. ASDAR uses a dedicated onboard processor connected to the aircraft avionics system and transmits observations automatically via the meteorological geosynchronous satellites of the International Data Collection System (IDCS). ASDAR uses hardware which was developed in the 1980's and was fitted to the aircraft, requiring relatively expensive and time-consuming certification and installation. It has the important advantage of using the meteorological satellite communications facility which is free for this type of message. On the other hand, ACARS uses the plane's own avionics system thus requiring no certification or alteration to the airframe. It does, however, use the airlines' communications system which could entail communication costs.

To date, a total of 20 units out of the 23 ASDAR systems originally purchased have been fitted on aircraft and are operational and reporting. Ten units are operational on aircraft of British Airways, three on KLM, two each on aircraft of Air Mauritius and South African Airways, and one each on aircraft of SAUDIA, Lufthansa, and Aerolineas Argentinas. An additional unit is being installed on an aircraft of SAUDIA; the final ASDAR installation will be installed on a second Boeing 747 of Aerolineas Argentinas in September 1998. ASDAR transmits one observation every 7 minutes in level flight and observations are also made at selected pressure levels in ascent and descent. The number of observations per day received from any one unit depends on how long the particular aircraft is in the air. This number of observations could be as high as 280, but on average the number per day is about 150. For the total ASDAR-equipped fleet, the average number of reports received is about 1,400 daily (due to routine maintenance of the aircraft and when the unit is inoperative). With regard to data coverage, about 50 percent of the ASDAR-equipped aircraft fly between Europe and North America, and the others to destinations in Asia, Africa, Australia, and South America. More than 85 percent of reports are received at Bracknell, United Kingdom within 1 hour and 99 percent within 2 hours. ASDAR data quality is high with a typical rate of rejected reports of less than 1 percent of all reports.

The United States AMDAR program, called Meteorological Data Communications and Reporting System (MDCRS), began in the early 1980's and is a cooperative effort among ARINC, the NWS, and the FAA. It grew slowly in the first 10 years, but has grown rapidly during the decade of the 1990's. Over 55,000 reports of wind and temperature are sent every day in the Binary Universal Form for Representation of Meteorological Data (BUFR) code. These MDCRS reports are provided by four airlines: Delta, Northwest, United, and United Parcel Service (UPS). American Airlines has just joined the program and will provide the full suite of data; Federal Express has agreed to supply their flight following data that includes weather information transmitted every 30 minutes.

Two new MDCRS programs are being developed: water vapor and turbulence. A new water vapor sensor was installed on a UPS B-757 aircraft and, over the next several years, up to 160 units are slated for installation on UPS and other airlines for a full test and evaluation of the sensor. A new turbulence algorithm, developed by the National Center for Atmospheric Research (NCAR) is being installed on approximately 200 United Airlines aircraft. Plans call for the turbulence algorithm to be installed on other carriers as well.

Large quantities of weather reports, particularly over oceanic and other data-sparse areas, will be realized via satellite communications and navigation systems. This source of data is of interest to the United States and others of the international aeronautical community, especially Numerical Weather Prediction (NWP) Centers including World Area Forecast Centers (WAFCs).

The Forty-Ninth Session of WMO's Executive Council (Geneva, June 1997) endorsed a proposal by the Operating Consortium of ASDAR Participants (OCAP) that a Panel on Aircraft Meteorological Data Reporting composed of Members of WMO that operate, or intend to operate, national AMDAR Programs to coordinate and promote global AMDAR development be established. The second meeting of the AMDAR Panel was held in Geneva, Switzerland, on October 19-22, 1999. The Inaugural Meeting of the Panel, held in 1998, provided the foundation for the implementation of the AMDAR Program and set out the goal to coordinate and promote global AMDAR development in order to enhance the upper air component of the GOS. Thirteen members and seven international organizations took part in the meeting.

In addition to these aircraft-based systems, other observation systems are being deployed to improve the GOS. For example, there has been deployment of substantial numbers of drifting buoys. A number of nations, including the United States, have implemented experimental or quasi-operational networks or single sites of ground-based Doppler radars called wind profilers to provide nearly continuous wind soundings. A network of 32 tropospheric wind profilers is being operated quasi-operationally at 404 MHZ primarily in the central part of the United States. Some threat exists to their continued operation because of the likely sale of the 404 MHZ frequency. Three new profilers operating at 449 MHZ are being installed in the State of Alaska later in 1998. Also a significant number of boundary layer profilers are being installed to monitor air quality. All the data from the tropospheric profilers are available on the GTS and on the Internet.

To improve the methodology used in developing and deploying observing systems, NOAA in 1997, established the North American Atmospheric Observing System (NAOS) program. The group has representatives from several federal agencies along with representatives from Canada and Mexico. NAOS objectives are to: (1) define a cost-effective, requirements-driven "best mix" of observing platforms and instruments and (2) reduce observing system risks and uncertainties. While the initial focus of the program will be to modernize the composite upper-air network, NAOS is expected to guide the resource-allocation process for most future observing systems developed and/or fielded by NOAA. Several projects of NAOS have been undertaken to assess the utility of the MDCRS data in numerical models, including the impact of replacing some numbers of rawinsonde sites with MDCRS soundings, an assessment of forecaster use of MDCRS, and the impact on short-range forecasting. These two studies are planned to be concluded in 1998.

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

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

Global Data Processing System

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

The GDPS is organized as a three-level system. It consists of World Meteorological Centers (WMC), Regional/Specialized Meteorological Centers (RSMC), and National Meteorological Centers (NMC). NMCs carry out GDPS functions at the national level. In general, real-time functions of the system involve preprocessing of data including real-time quality control, analysis, and prognosis, including derivation of appropriate meteorological parameters. The non-real-time functions include data collec-

tion and archival, and additional quality control, storage, and retrieval, to include cataloging observational data and processed information for operational and special applications and for research.

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

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

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

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

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

The gradual implementation of the final phase of the WAFS has begun and will continue over the next few years. The planned final phase call for the two WAFCs to prepare and issue computer-based wind and temperature forecasts as they now do. In addition, those centers will automate all of the significant weather elements. While some of these elements are now prepared automatically, others are developed through forecaster-initiated graphic interaction.

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

Global Telecommunication System

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

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

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

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

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

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

- GTS network redesign to take into consideration new technical opportunities, such as Internet-like services.
- Improvement of the capacity of MTN links and inclusion of graphics (e.g., Washington-Brasilia, Washington-Buenos Aires, Washington-Tokyo).
- Continued implementation of satellite-serviced data collection platforms to enhance the collec-tion 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. The need to convert WEFAX to LRIT and APT to LRPT formats will have to be undertaken during the next decade.

Voluntary Cooperation Program (VCP)

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

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

The DOS provides funding for VCP projects with NOAA administering and carrying out programs designed to aid meteorological/hydrological and climate projects in recipient countries.

VCP Projects for 2001 include:

- Implementation and updating of surface and upper-air observational programs in the tropics, the Southern Hemisphere, and Africa as resources and priorities permit.
- Support of WAFS applications and utilization.
- Continued support for the implementation of VCP projects in Latin America and the Caribbean areas in support of the hurricane and tropical storm programs.
- Connecting National Meteorological Services to the Internet as a low-cost way to collect and enhance a global data base.

BILATERAL AND REGIONAL INTERNATIONAL COOPERATIVE PROGRAMS

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

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

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

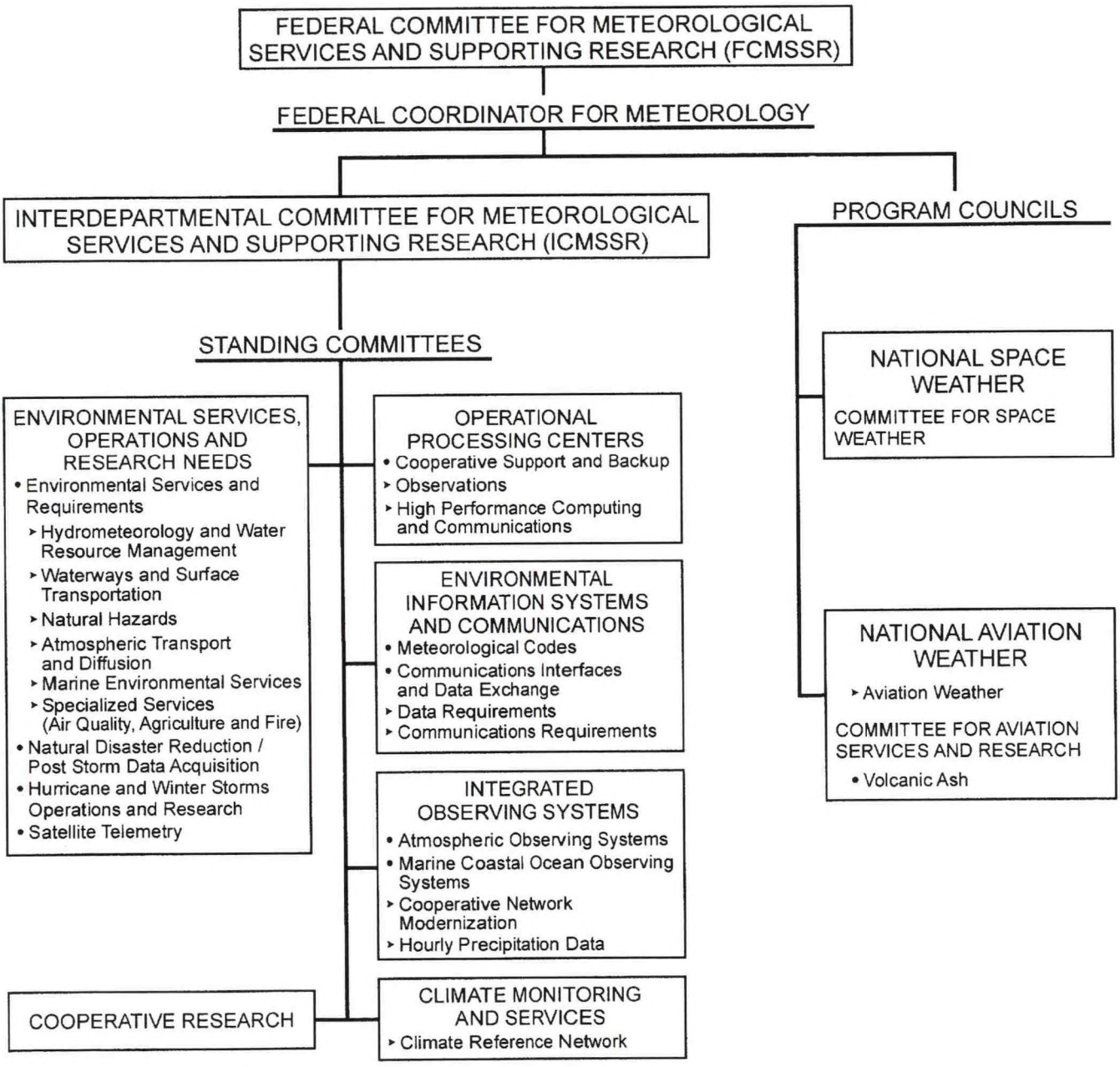
The cooperative activities between the United States and China under this program have decreased over the past 2 years. The main cooperative activity has been within the Training and Participation Program with a dozen Chinese scientists and trainees working at NOAA facilities for up to 18 months.

United States-Mexico Meteorological and Hydrologic Program

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

- The international dissemination of observations from meteorological and hydrologic observation systems.
- The exchange of meteorological, hydrologic, and related data and products between the United States and Mexico.
- The cooperation necessary to assure prompt transmission through telecommunications networks of these data and products.

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



JULY 1999

LEGEND: • Designates a Working Group
▸ Designates a Joint Action Group