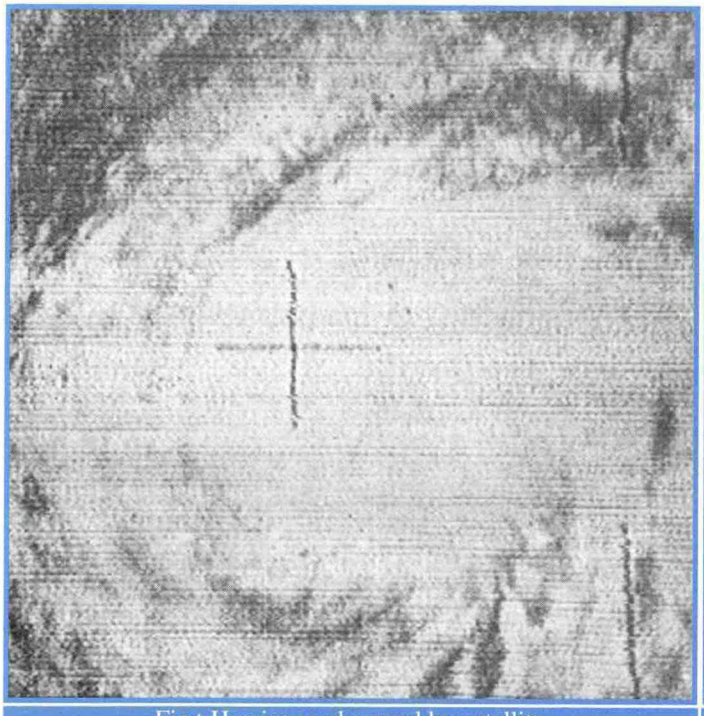
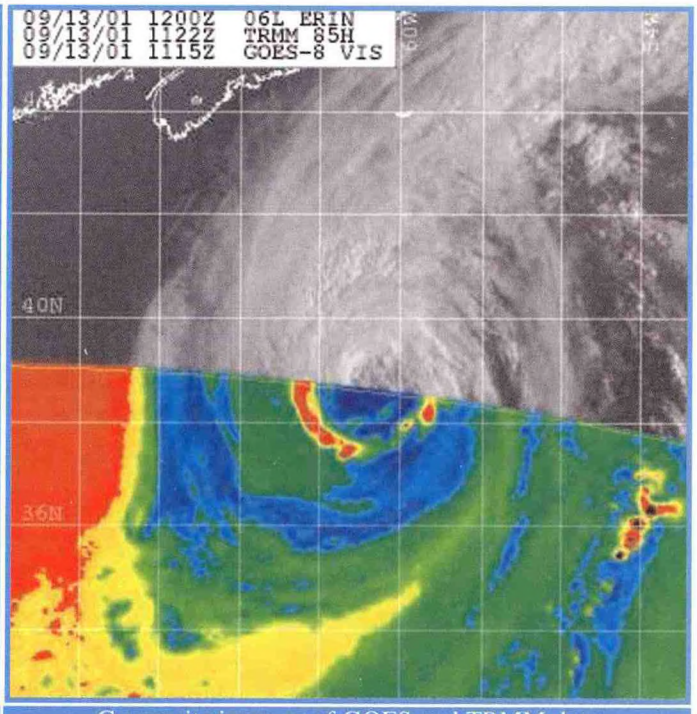
he Federal Plan
r Meteorological Services
and Supporting Research
Fiscal Year 2002



First Hurricane observed by satellite
1961 Hurricane Esther from TIROS III



Composite imagery of GOES and TRMM data
Hurricane Erin, 13 September 2001

OFCM

OFFICE OF THE FEDERAL
COORDINATOR
FOR METEOROLOGY

FCM P1-2001

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

Pictures displayed on the cover.

Left Panel: First TIROS imagery of Hurricane Esther; Source--NESDIS

Right Panel: GOES-8 and TRMM Composite imagery; Source--United States Navy Research Laboratory, Monterey Marine Division, Tropical Cyclone Page

The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 2002

FEDERAL COORDINATOR
FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

8455 Colesville Road, Suite 1500
Silver Spring, MD 20910

FCM-P1-2001
JUNE 2001
WASHINGTON, D.C.

Editor: Blaine Tsugawa
Assistant Editor: Kenneth Barnett

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) 2002 and reviews agency programs in FY 2001. Narratives, timelines, and schedules are current as of June 2001.

The Federal Plan consists of an Executive Summary, three sections, and Appendices. 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) is titled *Research to Operations: Bridging the Valley of Death*. The article examines examples of meteorological technology and research that have been successfully transitioned into the mission operations of several federal agencies. Section 2 summarizes the resources requested in the President's FY 2002 Budget and includes a comparison of the resources that Congress appropriated for FY 2001. 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 E describe the OFCM's coordination, program, and planning activities (Appendix A); summarizes the World Weather Program (Appendix B); draws attention to the National Space Weather Program and the inherent capabilities of the Federal Government's Space Weather Forecasting services (Appendix C); lists previous feature articles (Appendix D); and defines acronyms and abbreviations (Appendix E). 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.

This edition of the Federal Plan is issued in memory of Aerographer's Mate First Class Edward Thomas Earhart and Aerographer's Mate Second Class Matthew Michael Flocco who perished at the Pentagon on September 11, 2001, while on duty with the United States Navy.

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

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH, FISCAL YEAR 2002

TABLE OF CONTENTS

LIST OF TABLES

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH
FISCAL YEAR 2002
EXECUTIVE SUMMARY

For Fiscal Year (FY) 2002, the President's budget requests $2.7 billion for meteorological services and supporting research. Of the total requested, $2.31 billion is designated for operations and $389 million for supporting research. Table ES-1 lists a breakout of the FY 2002 budget proposal.

As in previous years, 92.8 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 59.1 percent, DOD 16.6 percent, and DOT 17.1 percent. The other federal agencies will share the remaining 7.2 percent.

In comparison to the $2.64 billion appropriated in FY 2001, the FY 2002 request represents an increase of 2.1 percent. Within the three major departments, DOC requests an increase of 10.1 percent while DOD and DOT requests decreases of 11.7 percent and 4.4 percent, respectively. The DOC increase is attributable to requests for increase by NWS, NESDIS, NOS, and OAR. The DOD decreases are attributable to DMSP (32 percent in DMSP operations and 51.2 percent in supporting research) and Army (TRADOC and AMC systems and acquisition funding). DOT's decrease is associated with FAA operations.

The budget requests for the other departments are as follows: Department of Agriculture (USDA) an increase of 0.4 percent, Department of the Interior (DOI) no change, Environmental Protection Agency (EPA) an increase of 17.2 percent; National Aeronautics and Space Administration (NASA) a decrease of 6.5 percent; and Nuclear Regulatory Commission (NRC) a decrease of 57.3 percent.

Figure ES-1 depicts each agency's proportion of the requested FY 2002 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 $2.31 billion requested for meteorological operations, DOC, DOD, and DOT account for slightly over 99 per-

Table ES-1. Federal Budget for Meteorological Operations and Supporting Research, FY 2002 (in thousands of dollars)

Agency	Operations	% of TOTAL	Supporting Research	% of TOTAL	TOTAL	% of TOTAL
Agriculture	$12,700	0.6	$15,500	4.0	$28,200	1.0
Commerce	1,485,104	64.4	107,832	27.7	1,592,936	59.1
Defense	376,109	16.3	71,479	18.4	447,588	16.6
Interior	1,100	0.0	0	0.0	1,100	0.0
Transportation	429,244	18.6	31,583	8.1	460,826	17.1
EPA	0	0.0	7,500	1.9	7,500	0.3
NASA	2,845	0.1	155,400	39.9	158,245	5.9
NRC	50	0.0	0	0.0	50	0.0
TOTAL	2,307,152	100.0	389,294	100.0	2,696,445	100.0

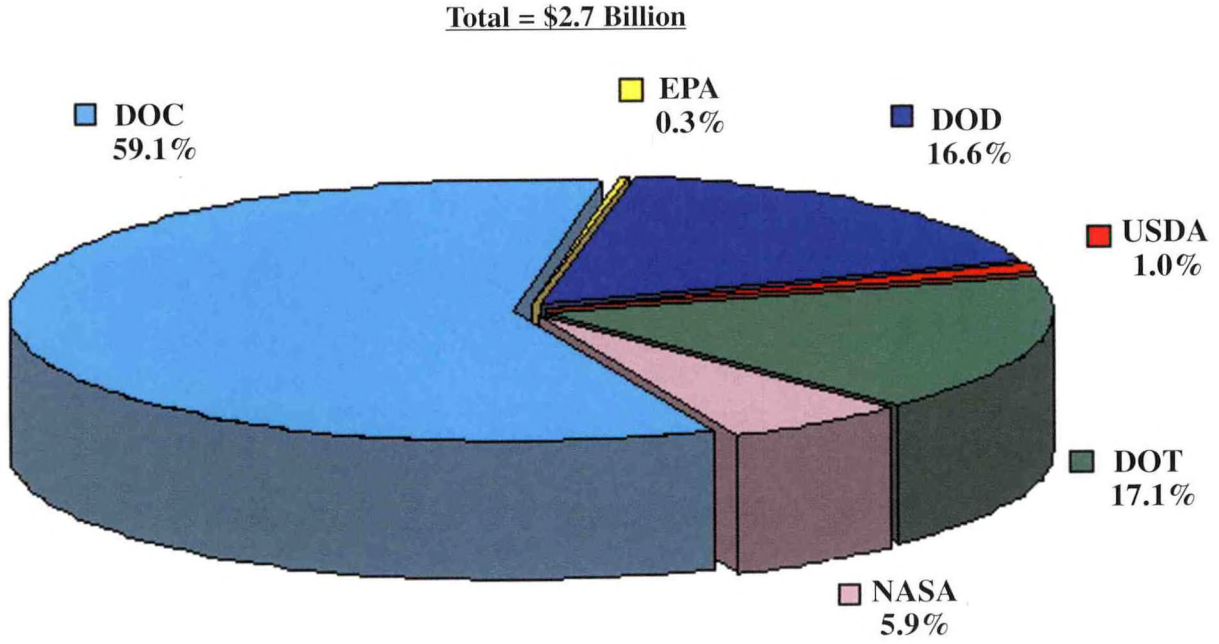


Figure ES-1. Agency Percent of Total Federal Budget for Meteorological Operations and Supporting Research, FY 2002.

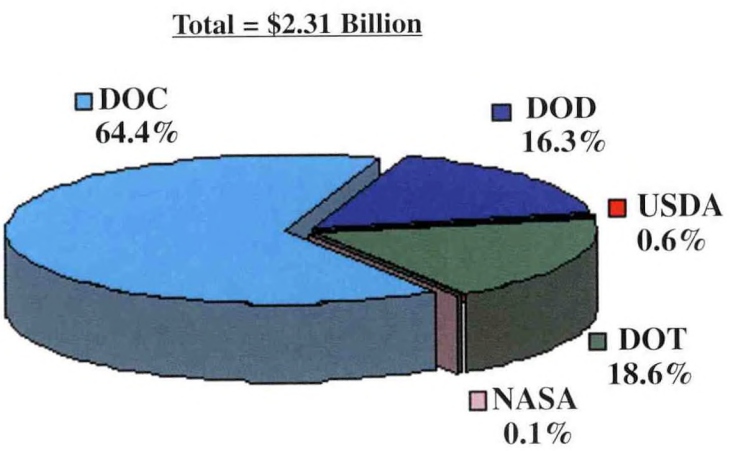


Figure ES-2. Agency Percent of Federal Budget for Meteorological Operations, FY 2002.

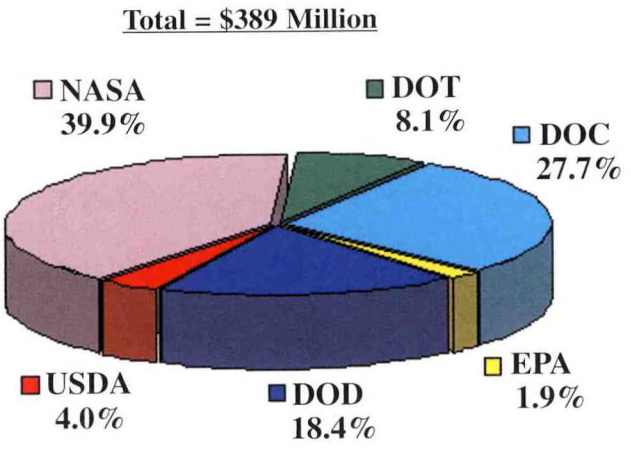


Figure ES-3. Agency Percent of Federal Budget for Supporting Research, FY 2002.

cent of the funds. Overall, operational costs increased by 3.7 percent. 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 (86 percent) of the supporting research budget. Requests for increases in supporting research funds are: DOC 5.0 percent, DOT 13.4 percent, and EPA 17.2 percent. The DOD and NASA requests for supporting research funds decreases by 26.9 and 6.2 percent, respectively.

All agencies project a personnel total of 14,410 full-time equivalent (FTE) to be employed in federal meteorological operations in FY 2002. This figure represents an increase of 0.6 percent from the 14,320 FTE employed in FY 2001.

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 2001, the DOC/National Weather Service had commissioned 123 sites, the DOD (USAF and Army) had commissioned 32 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 2001, 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 564 sites. The Navy has purchased, accepted, and commissioned 77 sites. The Air Force has purchased, accepted, and commissioned 34 sites. Collectively, a total of 989 ASOS sites have been commissioned. The remaining 5 FAA sites are scheduled to be commissioned by October 2001.

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 2001, 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 National Airspace System (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 the Automated Weather Distribution System (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 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.

OTHER AGENCY PROGRAMS

For FY 2002, the Department of Agriculture (USDA) requested $28.2 million for meteorological operations ($12.7 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 2002 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 $7.5 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 2002 is $155 million, which is 6.2 percent lower than the FY 2001 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 $50,000 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

55th Interdepartmental Hurricane Conference (IHC) (March 5-9, 2001). 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. The 55th IHC was held in Orlando, Florida. The theme for the conference was *Landfalling Hurricanes-A Major Challenge for Operations and Research in the 21st Century*. The conference was attended by over 210 people -- a new record, representing twelve federal agencies, the academic community, local emergency management, and the weather media. Special sessions were conducted on transitioning research to operations and the Hurricane Landfall component of the United States Weather Research Program (USWRP). The major outcome of the IHC was identification of the need for a sustainable, formalized approach to transition successful research results into the operational environment, which the OFCM will pursue through its Committee for Cooperative Research. In May, OFCM published the 39th edition of the *National Hurricane Operations Plan*, which details responsibilities of federal agencies; operations and procedures; products; aircraft, satellite, radar, and buoy data collection; and marine weather broadcasts.

National Hurricane Conference (April 9-13, 2001). OFCM sponsored a three-hour session attended by more than 200 individuals at the 2001 National Hurricane Conference with the theme *Toward a Safer America: Making the Nation More Resilient to Hurricanes*. The session included two distinguished panels which addressed managing the public's vulnerabilities and consequences through risk assessment and management, and improving hurricane preparedness and response through new communications technology and enhancing public outreach and education.

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 in the Tallahassee Florida area (northern Florida and southern Georgia) in mid-March 2001, and to examine flooding, ice jams, and levies in the area of the Red River near Grand Forks, North Dakota, in early April 2001. Aerial photographic support was provided by the Air Force's Civil Air Patrol (CAP). The

CAP support, negotiated by the working group and documented in a memorandum of understanding, has proven to be both timely and very cost effective.

Severe Local Storms Operations. In May 2001, the OFCM-sponsored Joint Action Group for Severe Local Storms Operations published the *National Severe Local Storms Operations Plan.* The plan outlines the responsibilities of the various United States federal agencies that provide meteorological services in observing, forecasting, and warning of severe local storms. It also defines meteorological terms used by the agencies preparing severe local storms forecasts and warnings; identifies differing operational warning criteria and procedures; and discusses communications, observations, and some public release aspects of severe storms warnings.

Transition Issues. The Federal Committee for Meteorological Services and Supporting Research (FCMSSR) met on November 14, 2000, in the Herbert C. Hoover Building, Washington, District of Columbia, to focus on issues that were relevant to the transition team for the next administration. The meeting was very successful and was attended by thirteen of the FCMSSR agencies. A white paper identifying and describing transition issues was prepared subsequent to the meeting and provided to the agencies for use in interactions with the transition team. Areas and issues identified were: (1) The Next Step Beyond Modernization (fully implement observational program; continue evolution of National Weather Service (NWS) systems); (2) Climate Services (implement global climate ocean observing systems; upgrade national computational capabilities); (3) Comprehensive Strategy for Emergency Management (support FEMA's *Project Impact*; support the Global Disaster Information Network; communicate rainfall and flooding information better); (4) Landfalling Hurricanes (improve hurricane track and intensity forecasts; follow and report on hurricanes after landfall); (5) Transportation (enhance weather information dissemination for aviation; improve accuracy of convective forecasts for aviation; improve road weather information); and (6) Strategy for Atmospheric Information (develop a strategy for atmospheric information; improve communication of weather and climate information).

Annual Federal Plan. OFCM prepared *The Federal Plan for Meteorological Services and Supporting Research -- Fiscal Year 2002.* The Federal Plan is Congressionally mandated and is a one-of-a-kind document which articulates the meteorological services provided and supporting research conducted by agencies of the federal government. The Federal Plan helps to reduce duplication among the agencies. It is a comprehensive publication that documents proposed programs for Fiscal Year 2002 and reviews agency programs in Fiscal Year 2001. The Plan demonstrates to the Congress and to the Executive Branch how the agencies work together to accomplish their missions in an effective and efficient manner.

Weather Information for Surface Transportation. OFCM has continued its extensive involvement in the area of 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, *Preparing for the Future: Improved Weather Information for Decision-Makers* was held December 4-6, 2000, in Rockville, Maryland. The symposium was attended by more than 100 individuals who were a cross-section of the transportation and weather communities (federal, state, and city governments, urban and rural transportation agencies, professional and trade organizations, and government and commercial weather service providers). Eight overarching areas of concern were identified and five specific action items were highlighted as needing priority for continued progress. The bottom line is that improvements in surface transportation weather support will result in safer and more efficient operations by all users.

OFCM also made substantial progress in preparation of a document addressing meteorological requirements for the six core modes of surface transportation: roadway, railway, transit, waterway, pipeline, and airport ground operations. This activity has included formation of a joint action group to address meteorological requirements for surface transportation; questionnaires; surveys; WIST symposia conducted jointly with the Federal Highway Administration; meetings with railroad, pipeline, and emergency managers; and participation on panels concerning public-private partnerships in transportation and Intelligent Transportation Systems. The requirements document will be a culmination of intensive OFCM efforts in this area and is expected to be published in November 2001.

Aviation Weather. OFCM completed its analysis of agency and industry programs/projects identified as meeting the needs and concerns contained in the January 1999 *National Aviation Weather Initiatives* document. A significant enabler in the process was the OFCM-sponsored July 2000 Aviation Weather User Forum. The forum provided an opportunity for open dialog between program managers as well as the users and providers of aviation weather information. The forum also played a significant role in completing the *National Aviation Weather Initiatives Tier 3 (Service Design)/Tier 4 (Budgets and Schedules) Baseline Report* which was issued in April

2001, a first-ever achievement for all government. The report was a major contribution toward establishing a baseline for ongoing and planned research and development for each initiative (requirements and products). The report will serve as a vehicle for transitioning research results into operations. Of the 86 initiatives, only ten have no agency identified as satisfying a particular need or concern. The next step will focus on key issues and actions identified during the Aviation Weather User Forum. One such issue is the need for improved aviation weather training and, in that regard, OFCM will take a leadership role in coordinating the establishment of a National Training Program. Another issue deals with establishing, validating, and prioritizing requirements. Now that we have established a baseline, the Joint Action Group for Aviation Weather will revisit the initiatives to determine if they continue to represent the priorities for aviation safety and efficiency. Consideration will also be given as to how best to meet the requirements for the ten initiatives identified that are not now being addressed by agencies or industry. OFCM is also continuing efforts concerning volcanic ash and expects to publish *A National Framework for Volcanic Ash Hazards to Aviation during FY 2002*.

Wind Chill Temperature Index. Under the leadership of OFCM's federal coordinating infrastructure, United States federal agencies, Canadian participants, and the academic research community have taken an important step towards improving the Wind Chill Temperature (WCT) Index. The new WCT Index will provide the citizens of the United States and Canada better protection of life and property. The current wind chill index attempts to measure the rate of heat loss by the human body as wind blows across it at different temperatures and speeds. The index was developed in the 1940s during an Antarctic expedition, and is now known to overestimate the effect of wind by at least ten degrees. This overestimate gives a false sense of security and people are sometimes not aware or prepared for the danger of severe winter weather. OFCM led the improvement effort by creating a Joint Action Group for Temperature Indices within its federal coordinating infrastructure, and this Joint Action Group pulled together the various United States, Canadian, and academic entities to develop the new WCT Index based on 21st Century science. Funding for the development of the new WCT Index was provided by OFCM, the United States Army's Cold Region Research and Engineering Laboratory, and the Defence Research and Development Canada. NOAA's NWS, the United States Air Force, and the Meteorological Service of Canada will implement the new WCT Index during the winter season of 2001-2002. This new WCT Index will be a substantial improvement over the current practice and will be based on a human face model, use wind speed calculated at the average height of an adult's face, incorporate modern heat transfer theory, lower the walking speed threshold used in calm wind situations, and use a consistent standard for skin tissue resistance. Later refinements will include adjustments for solar radiation for a variety of conditions.

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 (NSWP), 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 *NSWP Strategic Plan* and *Implementation Plans* provide, respectively, broad guidance and a detailed roadmap for the Program. The Committee for Space Weather (CSW) recently established the Community Coordinated Modeling Center (CCMC), with a mission to prepare the next generation of space weather models for transition to operations through the operational centers' rapid prototyping centers. During FY 2001, the fledgling CCMC transferred its first model to the Department of Commerce's Space Environment Center (SEC). The magnetohydrodynamic version of the Magnetospheric Specification Model will significantly improve the SEC's ability to predict the future state of the magnetosphere based on solar wind inputs. Nearing completion is work on coupling this model with a radiation belt model. During 2002, the CCMC will focus on ionospheric and heliospheric models and coupling ionospheric and magnetospheric models. In addition, the highly successful competition for space weather research grants, sponsored and administered by the National Science Foundation (NSF), will continue in 2002 with a modest increase in funding.

Strategy for Providing Atmospheric Information. OFCM is planning a forum to respond to the agency priorities and to address Leadership and Management Recommendation 1 of the National Research Council/National Academy of Sciences Board on Atmospheric Sciences and Climate (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." The Federal Coordinator began this effort by drafting a concept development paper which was provided to thirty agencies and individuals for feedback. The objective was defined to "Plan and promote the effective and efficient availability and distribution of atmospheric information that meets the requirements of all agencies (operational and research)." Major issues were identified to include: roles and responsibilities of the public and private sectors; availability of data (data receipt and distribution) and archival capabilities; health of the meteorological infrastructure; international commitments for free and open data exchange; and role of academic research, both basic and applied. The methodology would examine major issues in climate, natural hazards, technological hazards, urban meteorology and air quality, ecosystem management and agriculture, and aviation and surface transportation. The forum will be conducted in early December 2001.

United States Weather Research Program. The USWRP mission is to accelerate forecast improvements of high-impact weather and facilitate full use of advanced weather information. The USWRP's vision is to mitigate the effects of weather-induced disasters; reduce the costs associated with routinely disruptive weather; create opportunities for increased productivity through better weather information; and assist the military in the accomplishment of its mission. The current USWRP team includes NOAA as the lead agency, NSF, National Aeronautics and Space Administration, and the United States Navy. The Federal Coordinator has taken steps to contact additional agencies to broaden federal participation in the USWRP in accordance with an action from the Interdepartmental Committee for Meteorological Services and Supporting Research, direction from the Chairman of the Federal Committee for Meteorological Services and Supporting Research, and also recommendation from the National Academy of Sciences/ National Research Council Board on Atmospheric Sciences and Climate (BASC). OFCM hosted meetings on expanded agency participation in the USWRP on May 11 and August 24, 2001. The additional agencies included Federal Aviation Administration, FHWA, USAF, DOE, USDA, and FEMA. These meetings have led to more interaction directly between the leadership of the USWRP and interested agencies to discuss, in more detail, agency specific needs which may be benefited by the program. It is expected that several additional federal participants will join the USWRP and that the USWRP priorities will be expanded to address their needs.

Committee on Environment and Natural Resources. OFCM and the Committee on Environment and Natural Resources (CENR) Subcommittee on Natural Disaster Reduction (SNDR) cosponsored the Forum on Risk Management and Assessments of Natural Hazards February 5-6, 2001. The forum theme was *Toward a Safer America: Building Natural Hazard Resistant Communities through Risk Management and Assessments*. It was attended by an unprecedented cross-section of more than 120 weather, natural disaster and risk management professionals, and academia. Consensus was reached to proceed with a national natural hazard assessment and to develop an action plan which would deal with the assessment in manageable pieces. It was also agreed to integrate efforts with the Congressional Natural Hazards Caucus; develop improved partnerships between users and developers; standardize terminology, methodology, and approach within risk assessment and management; compile available risk assessment tools and models; and improve public outreach, education, and training.

American Meteorological Society. During FY 2001, OFCM joined nine 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 2002. OFCM also supports American Meteorological Society endeavors by participating in AMS conferences and workshops and other environmental science education and outreach programs.

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 2001*
- *National Hurricane Operations Plan*
- *55th Interdepartmental Hurricane Conference (Minutes)*
- *Proceedings for the Symposium Weather Information for Surface Transportation, Preparing for the Future: Improved Weather Information for Decision-Makers*
- *Proceedings of the Forum on Risk Management and Assessments of Natural Hazards*
- *National Severe Local Storms Operations Plan*

- *National Aviation Weather Initiatives Tier 3 (Service Design)/Tier 4 (Budgets and Schedules) Baseline Report*

The following documents are planned for publication during FY 2002:

- *The Federal Plan for Meteorological Services and Supporting Research -- Fiscal Year 2002*
- *National Hurricane Operations Plan*
- *56th Interdepartmental Hurricane Conference (Minutes)*
- *Weather Information for Surface Transportation (WIST) Requirements*
- *Proceedings for Workshop on BASC 21st Century Report Recommendation -- A Strategy for Atmospheric Information*
- *National Plan for Post-Storm Data Acquisition*
- *A National Framework for Volcanic Ash Hazards to Aviation*

During FY 2001, 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 2002.

RESEARCH TO OPERATIONS: *BRIDGING THE VALLEY OF DEATH*

INTRODUCTION

The National Research Council's *Crossing the Valley of Death* report highlighted the fact that as we move into the twenty-first century, the weather sensitive sectors of society continue to expand. They include energy generation, agriculture, forestry, fisheries, construction, tourism, transportation and navigation, public utilities, retail trade, finance, insurance and re-insurance, recreation, and real estate. The utility of timely and accurate weather information is diverse--it impacts military operations; commercial airline scheduling, operations, and flight planning; space launch scheduling; agriculture crop selection, planting, cultivation, and harvest timing; water resource management; and a wide range of commercial industries that schedule outdoor activities like construction and transportation. Information about extreme weather, especially that which puts life and property at risk, is essential for all sectors, but particularly for the emergency management and disaster relief communities. Both the public and private sectors have a growing demand for accurate information about and prediction of extreme weather, ocean, and climate events.

To meet this demand, the federal government organizes the nation's weather, ocean, and climate prediction responsibilities into two related areas. First, *operations* provide the basis for the production and dissemination of official forecasts and warnings. Additionally, operational services are divided between public sector predictions, both civilian and military, and private sector, value-added dissemination and prediction sevices. Second, *research, systems development, and technology development and implementation* are supported to improve the skill of weather forecasts. These activities are in some cases tightly coupled to operational efforts, while others have a weaker connection. Research is carried out in both federal laboratories and universities; however, in either case, it is largely supported by funding from the federal government.

PURPOSE

In the National Research Council's Report, *From Research to Operations in Weather Satellites and Numerical Weather Prediction--Crossing the Valley of Death*, it was stated that the term "Crossing the Valley of Death" is sometimes used in industry to describe the fundamental challenge of transitioning research and development (R&D) programs to operations. Operational implementation is frequently difficult, and, if done improperly, these transitions often result in "skeletons in Death Valley." The purpose of this article is to characterize the challenges ahead for the federal meteorological community with regard to the user demand for improved products and services and to propose an initial framework for transitioning successful research results to operations to meet that demand. The goal is to begin "building the bridge across the valley of death."

New Demands on the Forecasting Community

As a result of significant improvements in forecast capability achieved during the past decade, the demand for other specialized forecast applications--and the potential for new, substantial public benefits--has grown rapidly in recent years. The public has become accustomed to ever improving forecast products that are incorporated more frequently into daily decision-making. Weeklong forecasts, not viewed as credible two decades ago, are now an indispensable part of our planning processes. Other new products have also shown their worth. For example, solar ultraviolet radiation forecasts, developed by the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), alert beach goers to the need for sun screen and other precautions against harmful exposure to the sun.

It will soon be possible to deliver several new forecast products that will, at first, be unfamiliar to the public, but will become as indispensable as our present weeklong weather forecasts. They include:

- *Hurricane forecasts.* Threats to life and property and the costly and disruptive nature of evacuations have resulted in demands for improved hurricane forecasts of storm track, intensity, and precipitation. Hurricane Floyd in September 1999 had an economic impact of approximately $2 billion, while causing the largest peacetime evacuation in United States history. Improved forecasts of hurricane track and intensity will reduce the necessity and attendant cost of over-warning.
- *Lightning forecasts.* While lightning poses one of the greatest threats to life and property in the United States, at the present time, only general forecasts of lightning likelihood are produced (e.g.,

Article prepared by Mr. Robert Dumont, Senior Meteorologist, OFCM Staff.

60 percent chance of thunderstorms). With the increasing accuracy of small-scale weather system forecasting and better understanding of the physics of lightning, it will soon be possible to provide specific forecasts of lightning occurrences (i.e., the probability of lightning strikes at specific times and places).

▸▸ *Temperature forecasts.* Increasing concern over the consequences of energy production will result in demand for improved planning and operations in power production. Improved temperature forecasts will result in significant fuel-cost savings and a more efficient electric industry.

▸▸ *Seasonal outlooks.* The energy industries will also benefit from the improvements in seasonal to interannual forecasting, increasing the demand for products and services on that time scale. It has been estimated that the accurate seasonal outlook prior to the 1997-98 El Niño event allowed utilities to realize savings of about $500 million.

▸▸ *Air quality forecasts.* The strong link between air temperature and air quality and the associated negative impact of poor air quality on all aspects of human respiratory health are creating demands for a whole new suite of air quality forecasts.

▸▸ *Operational space forecasts.* Space weather hazards are becoming increasingly important to the performance and reliability of space-borne and ground-based communications and observation systems. With the development of increasingly sophisticated technologies and the expansion of human activities into near-earth space, there will be an increasing need to forecast the changing fluxes of energetic particles, geomagnetic fluctuations, short wavelength solar radiation, and other upper atmosphere/near space conditions. Fortunately, an unprecedented armada of spacecraft is providing the required data, and there has been tremendous progress in research modeling of space weather phenomena. The OFCM-sponsored National Space Weather Program now seeks to implement operational space weather forecasting based on these advances.

▸▸ *Water-related forecasts.* Clean, safe water is essential to human well-being. Recent research has uncovered some remarkable results that have significant implications for forecasting products. For instance, cholera outbreaks have been shown to be related to oceanic physical conditions and the resulting algal types and concentrations. Thus, we are now in a position to forecast the conditions leading to cholera outbreaks around the world. Other water-related forecasts dealing with water availability and quality will also be possible and will complement current drought and flood forecasts.

▸▸ *Climate predictions.* The potential links between climate variability and ecosystem impacts (food, forage, timber, fiber, water) were enumerated in the first United States National Assessment of Climate Change Impacts. The linkage is expected to result in a growing demand for improved projections of future climate conditions.

The demand for new and diverse forecasting products will continue to grow and, with implementation, these expanded products will promote increased human safety and stimulate economic benefits in the United States and elsewhere. However, until current and future research advances are effectively incorporated into operational forecasts, the nation will not realize the attendant benefits of its research investment. It is important to understand the transition process and to ensure its efficient operation. Otherwise, impediments that may now exist will become more problematic in the future as a consequence of the anticipated, expanded demands on the nation's weather, ocean, and climate forecasting capability.

Improving the Research to Operations Transition Process

The challenge facing the federal meteorological community is to reduce the impediments that limit the efficient transfer of weather, ocean, and climate research findings into improved forecast capabilities. The operational forecast system is responsible for collecting and assembling data, and for using that data, in conjunction with models, to produce forecast products in a timely fashion. Consequently, the system encompasses many elements, from instruments on land, on and under the ocean surface, in the atmosphere, and in space, to the computational resources required to create, display, and disseminate the products. All elements of the system can be improved, and both the private sector and the academic research and development communities can contribute to that improvement.

To improve the transition process, strong interaction between the research and operational communities must exist. If the research community produces new science, one would expect opportunities to improve operations to result. Without effective transitions or a dialogue between research and operations about system performance, however, improvements to the skill of the operational system will be slow. Based on current research understanding, state-of-the-art sensors, and computers, the potential forecast skill is expected to be higher than that of the current operational system. Verification of forecast skill and ongoing dialogue about performance should guide operational practices toward improvement. Key issues for an operational system are to ensure that transitions do indeed result in improvements and that the effort required for transi-

tion is not overly disruptive. Feasibility must be demonstrated for the entire operational process, and the production of additional weather, ocean, and climate information must be accompanied by considerations of its dissemination, use, and impact.

If new research results have sufficient value, then a transition to operational status is desirable. The major challenges in accomplishing such a transition are institutional. Observations, modeling and prediction, and information dissemination to users should be tightly linked, and financial support of the operational system and transitioning new technologies and capabilities into operations requires long-term commitment. Also needed is the commitment for continued interaction with the research community to promote the opportunities to advance the state-of-the-art. The continued dialogue between the research and the operational communities is needed to guarantee that the latest techniques and current knowledge are available to transition for operational use. Through this dialogue, the operational services will be able to keep abreast of the latest research; assess ongoing development in observing, data assimilation, and modeling systems and determine how the information can be improved; and interface with the user community in the design of new useful products.

Guidelines for the Transition Process

The National Research Council's Board on Atmospheric Sciences and Climate (BASC) selected the following criteria as key to the effective transition of research to operations for the field of weather and climate prediction:

- A strong research program, including understanding the role of the operational user community in the broader context of the weather prediction system.
- A healthy infrastructure for transition. The forecasting system needs an observation, technology, and modeling capability that serves as a foundation for research and permits the demonstration of the potential for useful new products without drawing resources away from the operational forecast system. There is a need for a long-term commitment of adequate resources to maintain both research and operational programs. Mechanisms should be developed to enable continuous development and maintenance of state-of-the-art capabilities.
- Strong interface with the user community.
- International observation and data access partnerships.
- Continuous evaluation processes of each of the components of the weather prediction system as well as its subcomponents.

THE DOD MODEL

Within the DOD, there is a methodology (Figure 1-1) to provide a continuum of funding from basic research (6.1) to applied research (6.2) to advanced technology development (6.3) to demonstration and validation (6.4) to operational implementation (6.4/Operations and Maintenance (O&M)), and finally to operations (6.4/O&M).

Fundamental or basic research involves both broad exploration and user-needs driven research and normally results in a peer-reviewed publication, journal article, or technical report. As a result, a new operational capability could result from either a "research push" or an "operations pull" scenario. Applied research then takes promising basic research results from initial development through proof of concept. At that point, advanced technology development funds are used to complete the development effort which includes the scientific validation of the proof of concept. This effort should result in a decision/recommendation on whether or not to proceed with the transition process.

With the decision to transition, the demonstration and validation (DEM/VAL) phase begins. User needs/requirements are further refined, and initial budget, risk, and cost-benefit analyses are completed. The objective is to complete a thorough technical validation and demonstration of the capability, to include simulated implementation. Deliverables, as specified, may include source code, model transition plan, validation test report, and preliminary standard documentation.

Based on the results of the DEM/VAL, the decision is made on whether or not to proceed with operational implementation. With the decision to proceed, the capability is integrated into the operational system, and a comprehensive evaluation is conducted under operational conditions. The evaluation includes an initial operations check followed by a thorough test which is conducted in accordance with the operational test plan. The deliverables include the operational test report and the final and complete standard documentation.

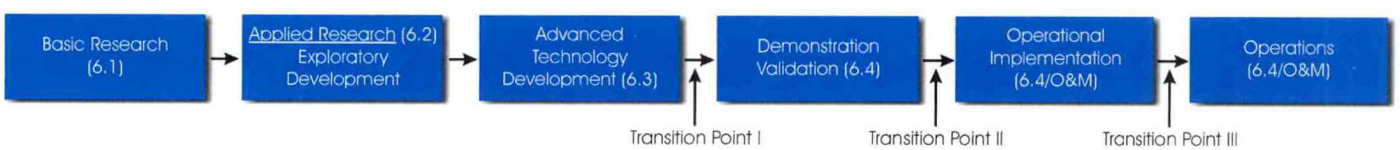


Figure 1-1. Department of Defense Transition Model.

The final point in the transition process is the decision to proceed with full implementation, which is made by the appropriate authority. At this point, the capability is fully integrated into the operational system. Validation, verification, upgrades, and fixes become ongoing operations and maintenance activities, which are part of the life-cycle support that is required until the capability is phased out. These activities are normally managed by the operational activity with the assistance of the developer.

The participants in the process include the researcher/developer, a technical validation panel to conduct the DEM/VAL in conjunction with the developer, the implementation panel to oversee the operational implementation and testing, and the operational activity which is the final user.

As an illustration, based on a requirement for tropical cyclone reconnaissance observations from the DOD's Joint Typhoon Warning Center (JTWC), the Marine Meteorology Division, Naval Research Laboratory, Monterey, California (NRL-MRY), developed the capability to provide reconnaissance information through the use of passive microwave (PMW) digital imagery. To date, NRL-MRY has completed the transition through demonstration and validation using 6.2 and 6.4 funding, and the capability is currently undergoing operational implementation at the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC), which is collocated with NRL-MRY. Full implementation into operations is scheduled for October 2001, assuming the operational testing and evaluation are successful.

NRL-MRY has provided the capability for near-real-time PMW imagery from both the Defense Meteorological Satellite Program's (DMSP) Special Sensor Microwave/Imager (SSM/I) and NASA's Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) to be available within 1-3 hours for tropical cyclones worldwide via the NRL-MRY tropical cyclone (TC) Internet Web page. The TC web page has significantly improved the availability and quality of PMW imagery/products for TC monitoring

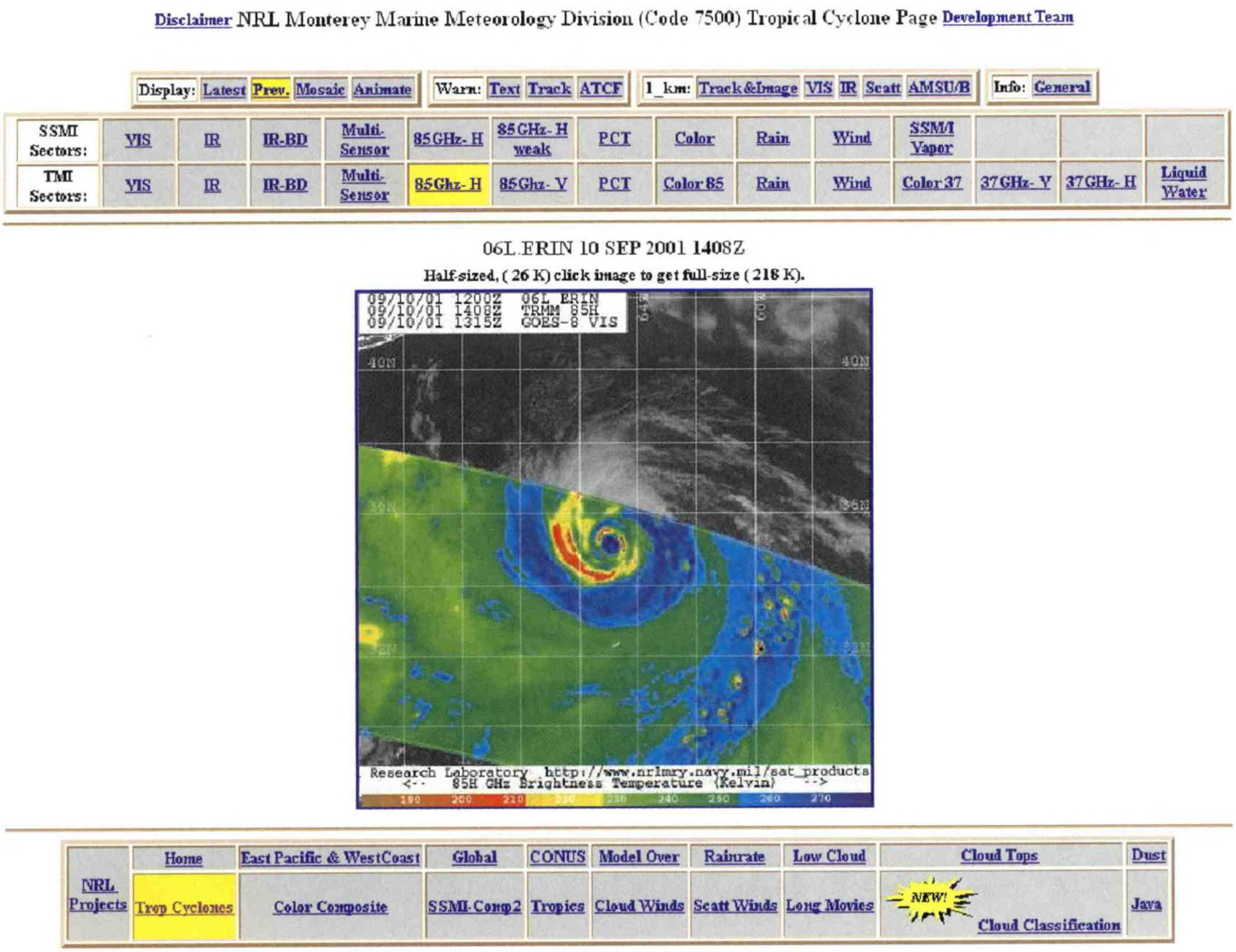


Figure 1-2. NRL-MRY web page for Satellite Products for Tropical Cyclone Reconnaissance.

around the globe. PMW data are basically a "poor-man's" radar since one can map the rainbands and TC organization not always seen in visible and infrared (IR) imagery (Figure 1-2). Distribution to a large audience of researchers, operational centers, and the general public has increased the awareness of how PMW data can be applied to increase the confidence in TC positioning and intensity estimates. The Internet has enabled NRL to carry out rapid prototyping with a superb feedback mechanism while users make suggestions for improved products and displays. While the reliability of the Internet was an early concern, the point has now been reached where JTWC and the NWS National Centers for Environmental Prediction's (NCEP) Tropical Prediction Center/National Hurricane Center (TPC/NHC) routinely access the NRL-MRY site (*kauai.nrlmry.navy.mil/sat-bin/tc_home*) in their search to assemble key storm characteristics. Once fully operational, FNMOC will maintain the Web site 24 hours-a-day and provide enhanced continuity. Figure 1-2 also illustrates the NRL-MRY TC web page to include the variety of products and capabilities that are made available to support the tropical cyclone forecast and warning effort.

The NRL-MRY demonstration via the Web has provided the operational user with a new tool to monitor TCs via PMW imagery. The learning process continues as the dataset expands, and new and improved sensors come online, which will nicely augment the existing dataset both temporally and with enhanced capabilities. Thus, the continued close working relationship between researchers and operators will provide future opportunities for TC applications, using passive microwave data in concert with collocated data that will increase the accuracy of TC location and intensity.

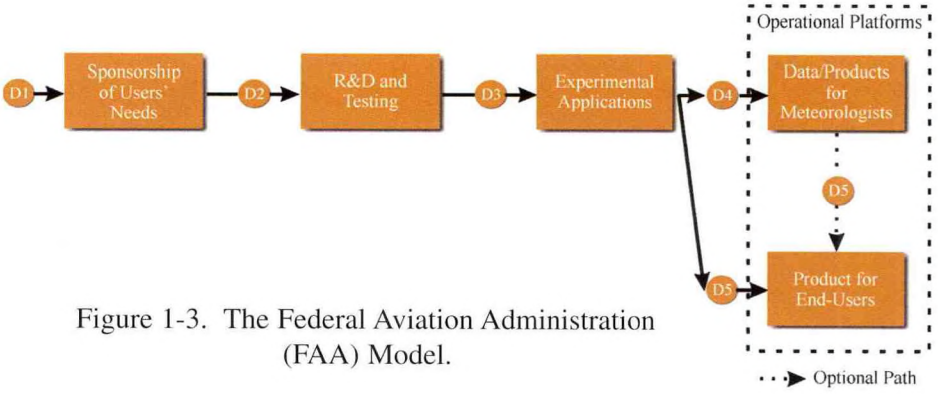


Figure 1-3. The Federal Aviation Administration (FAA) Model.

THE FAA MODEL

The FAA model is an "operations pull" approach; the goal is to accelerate the transfer of research and development into operations. The process begins with an analysis of user needs. Based on those needs and an initial concept of use (decision point 1), user advocacy or sponsorship is established. The user sponsor within the FAA (normally Air Traffic Services or Aviation Flight Standards Service) will assess the scientific and economic feasibility of producing the capability to meet specified performance metrics; i.e., the estimated risks of producing the capability or product, and then refine the concept of use/operations. The concept of use/operations includes, but is not limited to, the following: users' decisions requiring information, users' needs, performance metrics/thresholds, architecture, usage, training, accessibility, reliability, disclaimers, security, and a cost/benefit analysis.

With the decision to proceed (decision point 2), the research and development (R&D) project(s) needed to support the requirements are selected and funded. The deliverable is research-developed product or capability that is evaluated at decision point 3.

At decision point 3, the initial concept of use/operations and requirements are approved, risks are quantified, the initial scientific and technical review is conducted, the operations and maintenance budget is requested, the regulation and certification approval or approval plans is/are in place, and the acquisition process, if needed, is begun. Based on these inputs and the approval of the Aviation Weather Technology Transfer (AWTT) Board, the product/capability is released for experimental application and testing under an FAA test plan.

Once testing is successfully completed, the product/capability is released for operational use by the experts (meteorologists) (decision point 4), or it is released directly to the end user for operational use (decision point 5). At decision point 4, point 5, or both, the final concept of use/operations is approved, the scientific/technical review is completed and approved, the final regulation and certification approvals are in place, the budget is in place, and the acquisition process, if needed, is completed. The decision to release the product to the experts or directly to the end users or, as an optional path, through the experts to the end users rests with the AWTT Board.

The National Convective Weather Forecast (NCWF) was developed to satisfy both an operational meteorological and end-user requirement. Operational meteorologists will use the NCWF to prepare more concise convective hazard forecasts, and the end-users--pilots, airline dispatchers, and air traffic managers--will use the product to avoid flying into hazardous areas and to proactively help minimize schedule and flight disruptions.

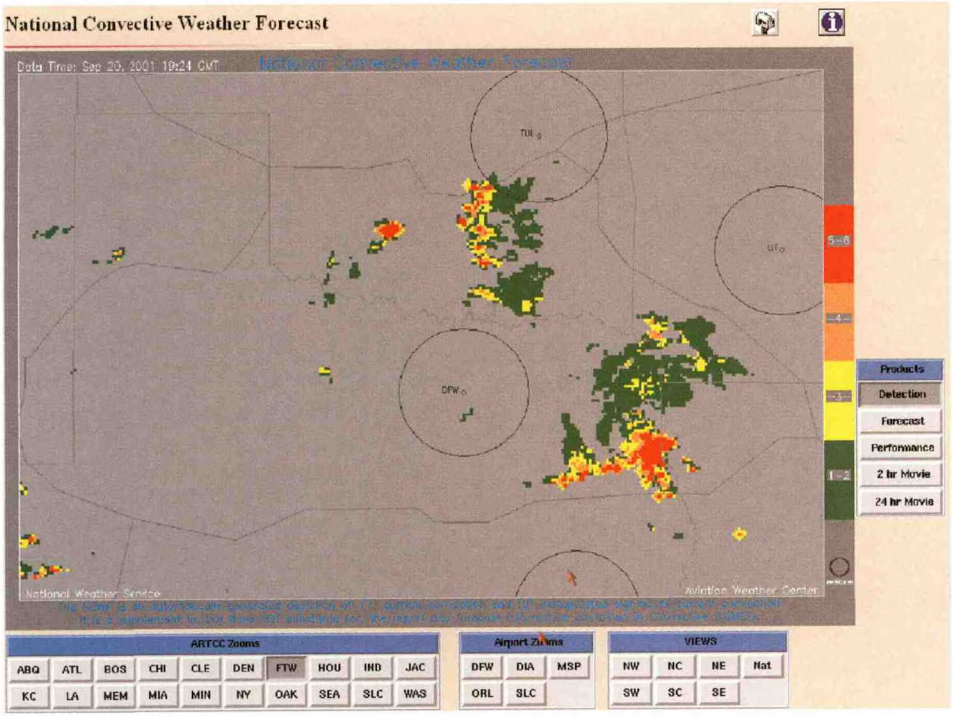


Figure 1-4. Example screenshot of the National Convective Weather Forecast.

Current research efforts have delivered the Stage I product, which is intended to complement current convective SIGnificant METeorological information (SIGMET) produced by the NWS NCEP's Aviation Weather Center (AWC). The NCWF is a 1-hour extrapolated forecast of the convection hazard detection field based on radar and lightning data (Figure 1-4). The convective SIGMETS are human-generated, 0-2 hour forecasts, issued every 60 minutes as simple polygon areas. In contrast, the Stage I NCWF is an automated, 1-hour forecast, issued every 5 minutes as a complex polygon area. The rather large areal extent of the convective SIGMET produces its trend to over-warn. The more compact and definitive NCWF, on the other hand, tends to under-warn new and growing storms, and over-warn dying storms. Stage I, however, is only the first step, and research is ongoing to extend the range of the forecast beyond 60 minutes and to improve the accuracy, especially during the growth and decay phases of convective storms.

To date, the implementation team has navigated the path from experimental application to operations. The final concept of use is approved, and the technical and regulatory reviews have been completed. The AWTT Board has approved the Stage I NCWF for implementation, and the NCWF will be implemented on the AWC production system in September 2001. In October 2001, *Air Transportation Operations Inspector's Handbook 8400.10* will be updated to authorize the operational use of the NCWF, and the air carriers will be notified. In January 2002, general aviation pilots will be formally notified through an update to the *Airman's Information Manual*.

THE COMPOSITE MODEL

If we take a systems approach to transitioning research to operations, we must begin with the definition phase--the user-needs analysis. The user could be an operational civilian or military meteorologist or oceanographer, or an end user like an emergency manager, aircraft pilot, or bus dispatcher. The user-needs analysis must identify what products or capabilities are needed to improve decision making and how good they must be to support the decision-making process; i.e., the performance metrics.

Similar to the FAA model, the user-needs analysis should generate an initial concept of operations, which includes at least the following: users' decisions requiring information, users' needs, performance metrics/thresholds, architecture, usage, training, security, and an initial cost/benefit and risk analysis. If research is needed to satisfy the user need for a new product or capability, then the scientific and economic feasibility of developing the product or capability should be assessed. Then, if development is feasible, a research plan should be developed.

We generally put research into two categories: basic or fundamental and applied. We also label the research infusion process as either "research push" or "operations pull." In the foreseeable future, we envision that both basic and applied research will be predominately user-needs driven--operations pull. We should, however, continue to encourage and fund broad exploration and scientific curiosity; i.e., basic research, because a research breakthrough could drive a significantly improved change in existing products and services--the classic research push.

The funded research effort, which should include close collaboration between the researchers and operations personnel, should evolve from basic research, if necessary, to applied research, then on to advanced technology development. The deliverable should be a research-grade product or capability which provides an initial proof-of-concept to meet the user need/requirement.

A technical oversight panel should conduct a scientific review of the technology and validate the initial concept of operations and proof-of-concept. The risks and benefits associated with implementing the new product or capability should be quantified, and the needed funding to proceed with the transition must be obtained. Plans should also include the operations and

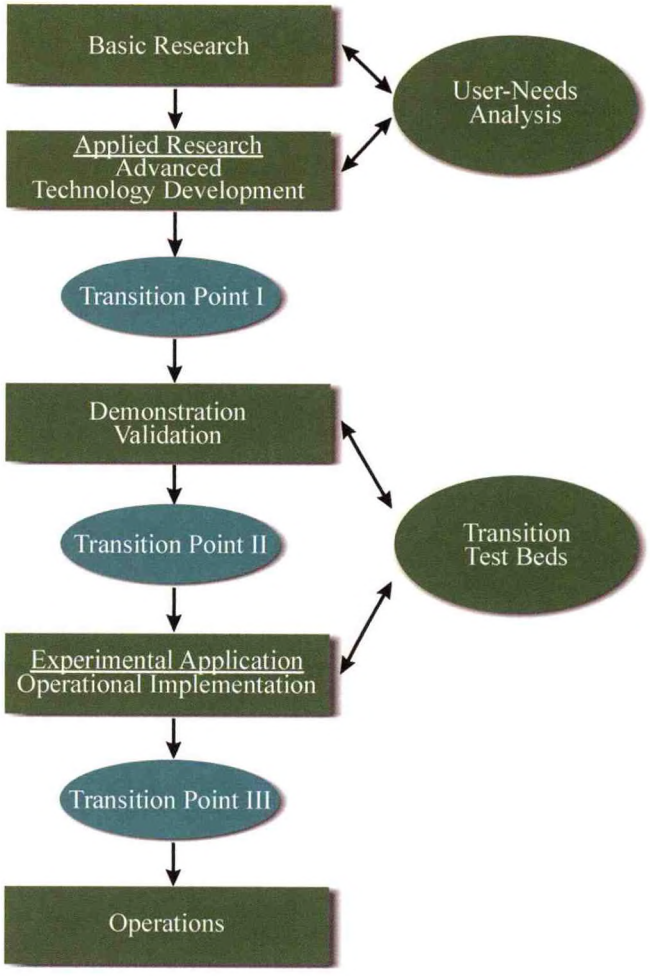


Figure 1-5. A Composite Model for Transitioning Research to Operations.

maintenance budget request to support operational implementation and life-cycle support once full operational capability is achieved. Based on the recommendation of the panel, demonstration and validation will proceed.

A technical validation panel of users, developers, and product managers should work together to validate and demonstrate the technical goodness of the product/capability, to include simulated implementation. The evaluation should include performance-testing and operational metrics initially documented in the concept of operations and refined by the panel. The deliverables should be a product or capability ready for operational implementation, together with preliminary standard documentation, anticipated training needs, and the validation test report. NOAA and the United States Weather Research Program (USWRP) have proposed a national testbed configuration (shown in Figure 1-6) which would significantly enhance the federal meteorological community's ability to conduct both demonstration and validation, and operational implementation, and the community should actively support its development.

With the decision of the technical oversight panel to proceed, experimental application or operational implementation is begun. The product or capability is integrated into the operational system or an optional testbed which could run in parallel with the operational system, and a comprehensive evaluation is conducted under operational conditions. The evaluation should include an initial operations check followed by a thorough test which is conducted in accordance with an operational test plan. The deliverables include the operational test report and complete standard documentation and training package to support the product/capability.

Based on the results of the operational test and the decision of the appropriate authority, the product or capability would be released for use by operational meteorologists or oceanographers or directly to the end-user or, as an optional path, through the operational users to the end users. At this point, the final concept of operations and scientific/technical review have been reviewed and approved, user requirements have been validated, and the operations and maintenance budget should be in place. Future upgrades and fixes, and ongoing verification and validation will be part of the life-cycle support to the new operational product or capability.

SUMMARY

In the "Crossing the Valley of Death" report, it was concluded that successful research-to-operations transitions require four things:

- An understanding of the importance (and risks) of the transition.
- Development and maintenance of appropriate transition plans.
- Adequate resource provision.
- Continuous feedback (in both directions) between the research and operational activities.

We would add to those conditions a clear understanding of user needs/requirements and administrative and technical oversight by the transition decision-makers throughout the process. Also, the testbed concept proposed by NOAA and the USWRP has tremendous potential to improve and facilitate the transition process and should be aggressively pursued.

The next step is to begin testing the framework, which should start with the development of a needs analysis for each user group within or served by the federal meteorological community.

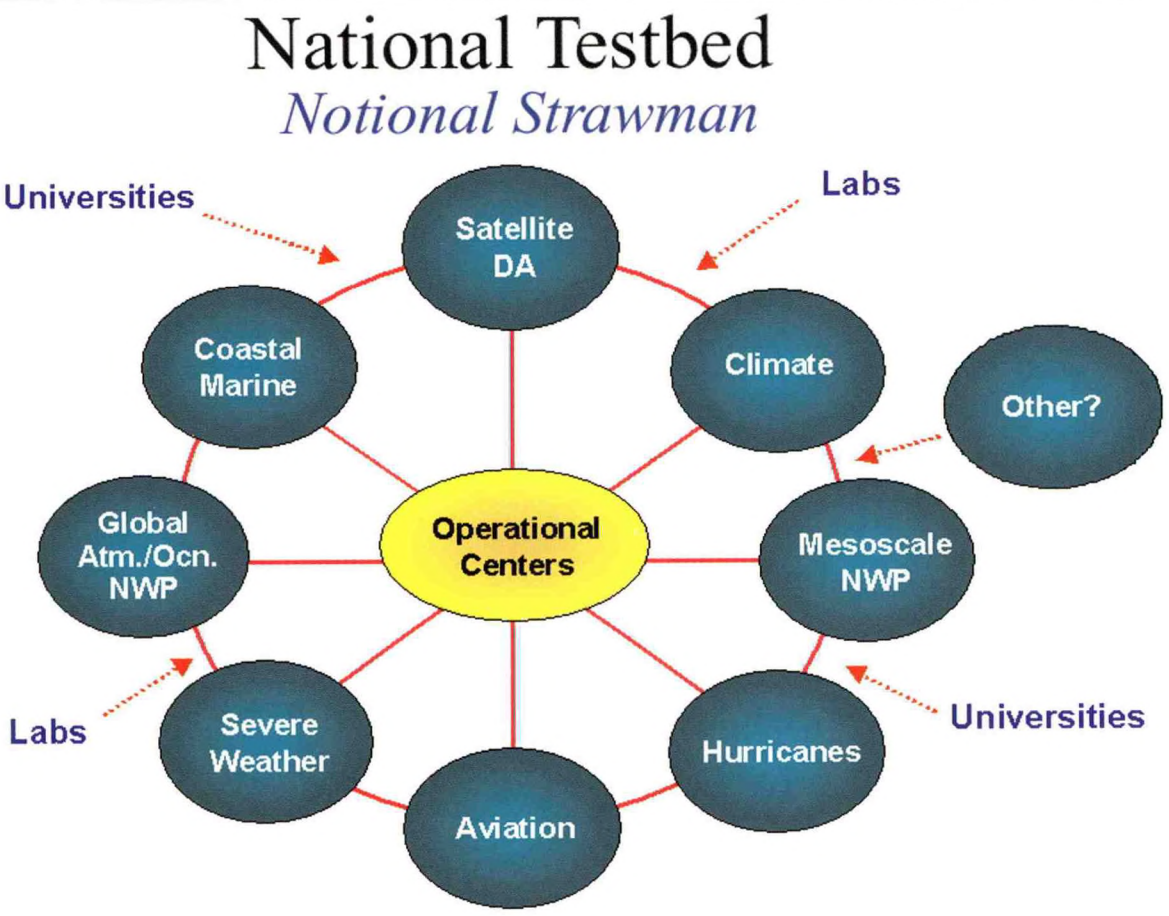


Figure 1-6. Proposed National Testbed Configuration.

The FAA has a head start with the aviation community, but that's only the tip of the iceberg. The demands on our community for improved products and services are only going to increase, and we need to have a process in place, plus the commitment of sufficient funding and resources, to meet those legitimate demands.

ACKNOWLEDGMENTS:

Portions of the article were excerpted from the National Research Council's report, *From Research to Operations in Weather Satellites and Numerical Weather Prediction--Crossing the Valley of Death*, 2000. Other references include Hawkins, J.D., T.F. Lee, J. Turk, C. Sampson, J. Kent, and K. Richardson, 2001: *Real-Time Internet Distribution of Satellite Products for Tropical Cyclone Reconnaissance.* Bull. Amer. Metero. Soc., 82, 567-578, and presentations given by the Navy's Naval Meteorology and Oceanography Command, the Federal Aviation Administration's Air Traffic System Requirements Service, and Air Traffic Systems Development, and the United States Weather Research Program.

SECTION 2

RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The tables in this section summarize budgetary information of the federal government for Fiscal Years 2001 and 2002. 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 2001 and are subject to later changes. The data for FY 2002 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) 2001 based on Congressional appropriations, the budget request for FY 2002, the percent change, and the individual agencies' percent of the total federal funding for FY 2001 and FY 2002.

DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 2002 is $28.2 million for operations and supporting research and representing a minor increase from FY 2001. One additional staff meteorologist was added to USDA's World Agricultural Outlook Board. 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 2002 total congressional request of $1.59 billion for meteorological programs represents an increase of 10.1 percent over the FY 2001 appropriated funds.

NOAA's FY 2002 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.

America's vulnerability to weather related hazards is rising as more of the population moves into weather threatened regions, 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 U.S. economy. In fact, the NWS was recognized last year 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 FY2002	Supporting Research			% of FY2002	Total			% of FY2001	% of FY2002
AGENCY	FY2001	FY2002	%CHG	TOTAL	FY2001	FY2002	%CHG	TOTAL	FY2001	FY2002	%CHG	TOTAL	TOTAL
Agriculture	12600	12700	0.8	0.6	15500	15500	0.0	4.0	28100	28200	0.4	1.1	1.0
Commerce/NOAA(Subtot)	1344501.5	1485104	10.5	64.4	102661.5	107832	5.0	27.7	1447163	1592936	10.1	54.8	59.1
NWS	692830	727606	5.0	31.5	23054	17414	-24.5	4.5	715884	745020	4.1	27.1	27.6
NESDIS	624999	727788	16.4	31.5	20172	24471	21.3	6.3	645171	752259	16.6	24.4	27.9
OAR	3000	3124	4.1	0.1	45094	48692	8.0	12.5	48094	51816	7.7	1.8	1.9
NOS	12872.5	15786	22.6	0.7	12872.5	15786	22.6	4.1	25745	31572	22.6	1.0	1.2
NOAA Corps	10800	10800	0.0	0.5	1469	1469	0.0	0.4	12269	12269	0.0	0.5	0.5
Defense(Subtot)	408866	376109	-8.0	16.3	97825	71479	-26.9	18.4	506691	447588	-11.7	19.2	16.6
Air Force	189315	184527	-2.5	8.0	42789	28467	-33.5	7.3	232104	212994	-8.2	8.8	7.9
DMSP**	36324	24687	-32.0	1.1	25139	12259	-51.2	3.1	61463	36946	-39.9	2.3	1.4
Navy	124797	123368	-1.1	5.3	12730	17893	40.6	4.6	137527	141261	2.7	5.2	5.2
Army	58430	43527	-25.5	1.9	17167	12860	-25.1	3.3	75597	56387	-25.4	2.9	2.1
Interior/BLM	1100	1100	0.0	0.0	0	0	0.0	0.0	1100	1100	0.0	0.0	0.0
Transportation(Subtot)	453985.2	429243.7	-5.4	18.6	27840.8	31582.5	13.4	8.1	481826	460826.2	-4.4	18.2	17.1
CG	6000	6000	0.0	0.3	0	0	0.0	0.0	6000	6000	0.0	0.2	0.2
FAA	447985.2	423243.7	-5.5	18.3	25110.8	28682.5	14.2	7.4	473096	451926.2	-4.5	17.9	16.8
FHWA	0	0	0.0	0.0	2730	2900	6.2	0.7	2730	2900	6.2	0.1	0.1
EPA	0	0	0.0	0.0	6400	7500	17.2	1.9	6400	7500	17.2	0.2	0.3
NASA	3472	2845	-18.1	0.1	165700	155400	-6.2	39.9	169172	158245	-6.5	6.4	5.9
NRC	117	50	-57.3	0.0	0	0	0.0	0.0	117	50	-57.3	0.0	0.0
TOTAL	2224641.7	2307151.7	3.7	100.0	415927.3	389293.5	4.0	100.0	2640569	2696445.2	2.1	100.0	100.0
% of FY TOTAL	84.2%	85.6%			15.8%	14.4%			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 2002 President's 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 2002, 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: Advance Short-Term Warning and Forecast Services, Implement Seasonal to Interannual Climate Forecasts, and 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.

Overall, NOAA requests a total of $727.6 million for the National Weather Service operations, a net increase of $34.8 million above the FY 2001 enacted. This includes a total of $658.5 million for Operations, Research, and Facilities (ORF) and $69.1 million for Procurement and Acquisition and Construction (PAC). In FY 2002, the budget priorities for NWS include sustaining current services, replacing obsolete technology, enhancing services to the public and its private partners, and infusing new technology.

Operations, Research, and Facilities

The FY 2002 President's Budget includes a request of $658.5 million which represents an increase of $29.0 million over the FY 2001 enacted. The increase allows NWS to maintain current services, begin modernization of the Cooperative Observer Network, and sustain operations at the National Centers for Environmental Prediction (NCEP). Specifically, the net increase of $29.0 million includes $24.3 million for Mandatory Pay Raises and Inflationary Costs, $1.2 million to restore the FY 2001 rescission, $1.9 million to sustain the Cooperative Observer Network, $1.7 million to sustain operational forecast models at NCEP's Environmental Modeling Center, $3.0 million to increase the NWS investment in data assimilation development efforts at NCEP including the NOAA/NASA Joint Center for Satellite Data Assimilation, and $0.3 million for Weather Forecast Office (WFO) Maintenance. In addition, the NWS request includes a reduction of $3.3 million to reflect completion of one-time activities or programs. The specific details on each of these requests are outlined below:

- Mandatory Pay and Inflationary Costs (+$24.3 million). NOAA requests an increase of $24.3 million to fund Adjustments-to-Base (ATBs) for NWS base operations and system accounts. The increase will fund the FY 2002 federal pay raise of 3.7 percent and annualize the FY 2001 pay raise of 3.7 percent. The increase will also provide mandatory inflationary increases for non-labor activities, including service contracts, field office lease payments, and rent charges from the General Services Administration (GSA).
- Restoration of FY 2001 Rescission (+$1.2 million). NOAA requests an increase of $1.2 million to restore the FY 2001 rescission. Restoration of these funds in FY 2002 is required to sustain NWS warning and forecast services to the Public. In FY 2002, NWS will restore funding to provide critical training for weather office staff, repair and maintenance of the NOAA Weather Radio network, and replacement of remote river and flood gage communication devices.
- Terminations (-$3.3 million). The NWS requests a decrease of $3.3 million to reflect the completion of the following one-time activities or programs: the Cooperative Institute for Regional Prediction in support of the 2002 Winter Olympics in Salt Lake City, Utah ($0.6 million); acquisition and installation of NOAA Weather Radio Transmitters at specified locations during FY 2001 ($1.9 million); Mt. Washington Observatory ($0.5 million); and the North Dakota Agricultural Weather Network ($0.3 million).
- Sustain Cooperative Observer Network (+$1.9 million). NOAA requests a total of $2.3 million to sustain the nation's cooperative observer network. The request represents a $1.9 million increase over the FY 2001 appropriation. 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 (NRC) 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 obsolete and increasing costly to maintain. In many instances, spare parts are no longer commercially available for these measuring devices.

In FY 2002, NWS plans to replace 900 rain gauges and

200 temperature sensors. This rescue effort will proceed over 3 years with the replacement of 2,700 rain gages and 5,000 temperature sensors.

- Weather Forecast Office (WFO) Maintenance & Repair (+$0.3 million). NWS requests a total of $4.6 million for WFO Maintenance, an increase of $0.3 million over the FY 2001 enacted level. The FY 2002 request will allow NWS to fund recurring maintenance contracts and address a backlog of over $7.0 million in deferred maintenance repair actions. WFOs provide forecasters with modernized facilities, supporting the advanced technology systems and the provision of weather service to the public. As the WFOs continue to age, the facilities 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.
- NCEP Environmental Modeling Center - Sustain Current Operations (+$1.7 million). NOAA requests an increase of $1.7 million to sustain operations at NCEP's Environmental Modeling Center (EMC). The EMC develops the computer models and other numerical forecast products which provide the basic guidance that forecasters use in making weather and climate forecasts. Today, the EMC is overly dependent on external sources of funding for its operations, degrading its ability to transfer proven weather forecasting science into NWS operations. The NRC report *From Research to Operations in Weather Satellites and Numerical Weather Prediction: Crossing the Valley of Death*, states "Almost all of the nation's operational weather and climate guidance products come from EMC, which does not presently possess the necessary resources to transfer many of the United States advances in observations and modeling to operations." In FY 2002, NWS plans to provide direct base support for its suite of operational forecast models, including the aviation, regional, and global models.
- NCEP Data Assimilation and Modeling (+$3.0 million). NOAA requests $3.0 million to improve to data assimilation and modeling at NCEP. Data assimilation is the collection and processing of weather observations (satellite, aircraft, radar, data buoys, upper air balloons) for use in operational numerical weather prediction models. These models are the foundation for all general weather forecasts (2 days and beyond) including aviation, marine, hurricane, rainfall, and severe weather. The objective of this critical funding request is to improve forecasts through the use of enhanced satellite data and other data sets in the NCEP prediction models, leveraging the nation's large capital investment in global observing systems. These activities will be implemented through the NOAA/NASA Joint Center for Satellite Data Assimilation which is funded in part through this initiative. Today, only 1/7th of the nation's satellite data are utilized in operational weather forecast models and too few resources are available for new data assimilation. The NRC report *From Research to Operations in Weather Satellites and Numerical Weather Prediction: Crossing the Valley of Death*, states "In most cases, when new sensors are developed, insufficient budget is provided to develop algorithms necessary to introduce those sensors into the operational system. There is limited capability to address the special needs associated with assimilation of large volume of new satellite observations." The report also stated the slow pace of improving weather prediction models could place United States industry at a competitive disadvantage and potentially impact National Security. In FY 2002, NWS plans to provide critical funding support to the NOAA/NASA Joint Center, enhance efforts to develop a community weather prediction model, and improve assimilation of new satellite data sets into NCEP operational prediction models.
- Advanced Hydrologic Prediction Service (AHPS). In FY 2002, 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. AHPS is already improving both the lead time and accuracy of flood forecasts as well as water resource management by extending river flood stage forecasts from days to months in the future. The AHPS is also providing new probability forecasts for rivers, providing critical information which can be used by water resource and emergency managers for risk based decision making. The Service has been successfully tested on major river basins in North Dakota, Iowa, Georgia, West Virginia, and Pennsylvania. Once deployed, AHPS will save lives and provide over $600 million in annual savings to the United States economy.
- Systems Operations. NOAA requests a total of $84.1 million in Systems Operations, an increase of $2.7 million from the FY 2001 enacted level. The Systems

Operations total includes $40.0 million for NEXRAD Operations and Maintenance (O&M), $7.6 million for ASOS O&M, and $36.5 million for AWIPS O&M. The FY 2002 increase is required to fund $2.5 million in Adjustments-to-Base (ATBs) related to the federal pay raise and inflationary costs as well as restore $0.2 million for the FY 2001 rescission.

Procurement, Acquisition and Construction (PAC)

As indicated above, NOAA requests $69.1M for NWS PAC, an increase of $5.7 million over the FY 2001 enacted. The specific requests are listed below:

- Automated Surface Observing System (ASOS) (+$1.3 Million). NOAA requests a total of $5.1 million for the ASOS PAC account, an increase of $1.3 million over the FY 2001 enacted. These funds are required in FY 2002 to ensure planned completion of the new ASOS dewpoint sensor acquisition (the highest failure rate sensor in the ASOS suite), and ASOS processor unit acquisition (current processor over capacity), and begin acquisition of the all-weather precipitation gage necessary for climate record continuity and aviation safety. Specifically, in FY 2002, the NWS will complete acquisition of 346 dewpoint sensors, and 346 processors; deploy 314 processors; and acquire 115 all-weather precipitation gages.
- NWS Telecommunications Gateway Backup - Critical Infrastructure Protection (+$7.4 Million). NOAA requests a total of $7.4 million to provide critical infrastructure protection for the NWS Telecommunications Gateway (NWSTG). The NWSTG is the nation's critical telecommunications hub for collecting, processing, and distributing weather data and information. The data processed by the NWSTG are used by hundreds of customers world-wide, affecting a wide-range of economic and emergency management decisions. These users include: the NWS WFOs and NCEP, the private meteorological industry, broadcast media, foreign countries, and the United States military. The current NWSTG facility, located in NWS headquarters in Silver Spring, Maryland, has no operational back-up and is therefore a single point of failure vulnerable to natural disasters, human error, computer viruses, hacker attacks, and terrorism. The requested funding increase will enable the NWS to acquire the equipment and facility infrastructure necessary to ensure continuity of operations at the NWSTG. Today, if the NWSTG were to fail, 90 percent of weather observations required for weather prediction models would be lost; no national radar or prediction models would be sent to the field; no weather observations or products would be sent to commercial users/vendors; no access or exchange of observations and products with other federal agencies or nations would be possible; and all NWS centrally provided Internet services would be halted. This investment will mitigate these risks and will enable the NWS to comply with Presidential Directives on critical infrastructure protection and continuity of government operations.
- NWS Weather Forecast Office (WFO) Construction (+$2.5 million). NOAA requests a total of $12 million to continue critical facility modernization efforts in the National Weather Service. The request represents an increase of $2.5 million over the FY 2001 appropriation. In FY 2002, NWS plans to finalize construction of the new Weather Forecast Office in Caribou, Maine and complete the new Alaska Tsunami Warning Center in Palmer, Alaska. NWS also plan to complete modernization of the weather offices in Hilo, Hawaii, and Kotzebue, Alaska.
- NEXRAD. NOAA requests a total of $8.3 million for the NEXRAD PAC account. The request will allow NWS to continue NEXRAD Product Improvement (NPI) activities by infusing new technology into the current radar network. The current system processor utilizes obsolete technology developed in the late 1980s. As a result, a number of new forecast and detection techniques, that are tested and ready for operational use, cannot run on the current system. Combined with AWIPS build 5.0 technology, NEXRAD NPI will allow NWS forecasters to improve the lead times for tornado warnings and the accuracy of severe thunderstorms forecasts. In FY 2002, NWS will complete critical hardware retrofits on a total of 126 NWS NEXRAD sites.
- AWIPS. NOAA requests a total of $16.3 million for the AWIPS PAC Account. In FY 2002, NWS will complete a three year effort to develop and deploy AWIPS build 5 software. NWS plans to deploy AWIPS build 5 in three major builds (5.0,5.1,5.2) over a 3 year period, beginning in October of FY 2000 and ending in October of FY 2003. In FY 2002, NWS will complete the distribution of build 5.1 and 5.2 after a rigorous test and evaluation process. AWIPS build 5 technology will provide NWS field forecasters with critical warning decision support systems to monitor and prioritize severe weather systems, automated product generation to improve efficiency, and improved radar and satellite display imagery. Combined with NPI, AWIPS build 5 will allow NWS forecasters to significantly improve

tornado warning lead times and improve the accuracy of severe thunderstorms forecasts.

- Central Computer Facility - NWS Weather and Climate Supercomputing. NOAA requests a total of $15.1 million to operate and maintain the NWS (Class VIII) Weather and Climate Supercomputer located in the Census Facility in Bowie, Maryland. The NWS supercomputer is the foundation for all NWS weather and climate forecasts. In FY 2002, NWS plans to improve weather forecasts by improving the resolution of the regional weather model (Eta) from 22 to 12 kilometers and the global weather model from 75 kilometers to 55 kilometers. The NWS also plans to improve and expand operational climate forecasts and implement a new regional climate model. NWS will continue to issue the Drought Monitor, Climate Threats Assessment, and the Extreme Heat Index. NWS will also utilize the supercomputer to improve forecasts for El Niño and La Nina events, and other climate oscillations.
- Radiosonde Replacement Network. NOAA will continue the replacement and modernization of the upper air radiosonde network . The PAC request includes a total of $5.0 million for this activity in FY 2002. The radiosonde network provides critical upper air observations for NWS weather forecasters and serves as the principal data source for all weather forecast models. The current network is obsolete and nearing collapse, risking widespread loss of data within the next two to three years. In FY 2002, NWS plans to complete the third year of a five year modernization effort by replacing 35 (out of 102) ground tracking systems. NWS also plans to replace the remaining obsolete IBM XT microcomputers that are used to track and process data.
- Evansville Doppler Radar (-$5.5 million). This decrease reflects the completion of one-time costs associated with the planned acquisition, deployment, and installation of a Doppler weather radar for the Evansville, Indiana, area during FY 2001.

Environmental Satellite, Data, and Information Services

Proposed funding for FY 2002 includes an increase in the Polar-Orbiting Satellite Program of $93.0 million and an increase in the Geostationary Satellite Program of $3.1 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 2002 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 $16.3 million is included to maintain basic mission services including maintenance and operation of satellite ground facilities; provision of satellite-derived products, including hazards support; and conduct of research to improve the use of satellite data. An increase of $0.75 million is requested to accelerate the assimilation and use of satellite-based data in numerical weather prediction models and an offsetting decrease is included as the result of reducing funds for the Global Winds Demonstration Program (-$1.993 million).

Budgetary changes netting to a decrease of $9.5 million are included in the NOAA Data Centers and Information Services subactivity. The changes include an increase in base operating funding (+$4.3 million). Decreases include elimination of funding for Regional Climatic Centers (-$2.9 million), reductions in Coastal Data Development (-$1.4 million), and reductions in funding for Data Preservation (-$9.5 million).

Ocean Service

Funding provided through the FY 2002 budget should allow the initial steps of the second generation of the NOS CO-OPS advanced data quality control program, the Continuous Operational Real-time Monitoring System (CORMS II), as well as the implementation of its development program of the Ocean Systems Test and Evaluation Program (OSTEP). NOS considers the size of the problem for these projects to be $5.0 million per year.

Under the budget initiative "Promote Safe Navigation" Implementation Plan FY 2002-2006 (when approved in present form), adequate funding would be available by FY 2006 and beyond to satisfy user requirements, and provide the necessary up-to-date high resolution predictions of all navigationally significant weather and oceanographic conditions for a national PORTS™ network.

Office of Atmospheric Research

Requested funding for FY 2002 for Weather Research and Solar-Terrestrial Services and Research is $51.8 mil-

lion--a net increase of $3.7 million. Increases included a base adjustment of $1.7 million to partially cover inflationary cost increases as well as a very small base restoration of $0.1 million. There also were programmatic increases of $2.2 million for the United States Weather Research Program, directed principally toward improving hurricane track predictions. A program decrease was also requested to terminate the $0.3 million "STORM" Program at the University of Northern Iowa. Finally, the space-based wind profile lidar technology add-on for incorporating wind profile data into forecast models was incorporated into the Weather Research base program.

DEPARTMENT OF DEFENSE (DOD)

The DOD total budget request for FY 2002 is $447.6 million which represents a funding decrease of 11.6 percent from FY 2001. 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 into several categories: general operations, investment and research, DMSP operations, and DMSP and National Polar-orbiting Operational Environmental Satellite System (NPOESS) supporting research. The Air Force request (including DMSP and NPOESS) for FY 2002 is $249.9 million.

General Operations: The operations portion of the FY 2002 budget request is $184.5 million and provides the day-to-day environmental support to the DOD. These funds will pay for 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 Supporting Research: The FY 2002 budget request for Air Force supporting research is $28.5 million. The Air Force continues development of the Space Weather Analysis and Forecast System (SWAFS). This project and 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 National Weather Service (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 2002 budget request is $24.9 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 2002 budget for DMSP R&D is $12.3 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 2002 DOD R&D budget for NPOESS is $157.4 million. FY 2002 funds will be used for the development of system architecture, technology development efforts, and 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 2002 budget request for meteorological programs is $141.3 million. The request includes $123.4 million for operational programs and $17.9 million for supporting research.

The Navy Meteorology and Oceanography (METOC) program is truly unique. Focusing support in the 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 support 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 Center, 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 perfomance.

United States Army

The United States Army has programmed $43.5 million for operational support and $12.9 million in research and development in FY 2002. Operational support is projected to decrease approximately $14.9 million over the FY 2001 expenditures, research is estimated to decreases about $4.3 million from the previous year, and real staffing should increase slightly. Systems upgrades and acquisition at TRADOC and AMC funded in FY 2001 but not in FY 2002 account for the bulk of the projected decrease in funding for the Army in this year's report.

The Eighth United States Army has programmed $1.28 million to fund weather operations during FY 2002. This includes $710,000 for Army ARTYMET operations, $5,000 for the upgrade and maintenance of new FALOP systems, $40,000 for the purchase of new automated COTS observing systems for the DMZ area and other locations in the ROK, and $520,000 for USAF weather support.

United States Army Europe has programmed $2.38 million to fund weather operations during FY 2002. $2.09 million is targeted for operational support, such as Artillery Meteorology, exercise support, and supplies, infrastructure, and automation related to meteorological support. USAREUR estimates costs of $295,000 for special programs related to training and operations and maintenance.

The United States Army Special Operations Command (USASOC) provides Army funding 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. USASOC has programmed $45,000 for these expenses in FY 2002.

USARPAC has programmed $220,000 for FY 2002, an increase over the $185,000 for FY 2001. This delta is due to IMETS operations and maintenance costs of the two units at 172nd SIB and 25th ID. These costs are estimated at approximately $16,000 each per year. In addition, a one-time requirement of $3,000 will be used to install a lightning detection system at the recently activated 17th Operational Weather Squadron. This will enhance resource protection of Oahu Army installations with a real-time lightning detection meteorological watch.

Forces Command has programmed approximately $7.18 million in FY 2002 for Operations Support. Of this amount, $560,000 will be targeted

for facilities, supplies, and travel for FORSCOM weather teams, and $6.62 million for support of FORSCOM ARTYMET operations.

DEPARTMENT OF THE INTERIOR (DOI)

The DOI/BLM funding request for FY 2002 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 includes personnel, vehicles per diem, normal procurement and facilities).

The BLM optimization effort in RAWS will continue in 2002. 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 cost savings in operations costs will be used to replace aging equipment and upgrade sensors packages. Proposed changes in Lightning Detection operations will further reduce the out-year expenditures in this program. Coordination between DOI agencies and the USDA Forest Service regarding combined meteorological requirements for the National 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 DOT total budget request for FY 2002 is $460.8 million which represents a funding decrease of 4.4 percent from FY 2001. The meteorological programs for the Federal Aviation Administration, Federal Highway Administration, and the United States Coast Guard for FY 2002 are described below:

Federal Aviation Administration (FAA)

The FAA request for aviation weather in FY 2002 is $451.9 million for both operations and supporting research; the FY 2001 funding was $473.1 million. The changes in the budget are decreases (5.5 percent) for operations (acquisition and operational support) from $448 million to 423.2 million while supporting research has increased (14.2 percent) from $25.1 million to $28.7 million.

In FY 2002, the requested funding for system acquisitions decreases by 22.5 per cent to $96.2 million. This change reflects major progress as a number of systems are being commissioned in the field 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)	2.1
Terminal Doppler Weather Radar (TDWR)	-2.1
New Generation Runway Visual Range (NGRVR)	-5.0
Integrated Terminal Weather System	-8.2
Automated Surface Observing System	3.2
Weather System Processor	-18.6
Stand Alone Weather Sensor	-3.2
NEXRAD Enhancements	2.9
Operations Support:	
Contract Weather Observations (CWO)	-5.0
Flight Service Stations	4.6
Research	
Aviation Weather	3.6

The request for funding in FY 2002 increases by $2.4 million to $319.1 million. The change reflects a large decrease in costs for CWOs which is countered by large increases in personnel salaries. Other changes are smaller and reflect normal adjustment to support costs both up and down.

The Aviation Weather Research Program (AWRP) has requested an increase in funding for FY 2002 of 14.2 percent for a total program of $28.7 million. The AWRP will continue work on the operational impacts of weather phenomena which threaten safety and efficiency.

Federal Highway Administration (FHWA)

The total FHWA request for surface transportation weather programs in FY 2002 is $2.9 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. A multi-year effort has been undertaken by the FHWA in cooperation with six national labs to prototype and field test advanced decision support components for winter maintenance. This effort will lead to an operational test of the MDSS, as well as produce decision support components that private vendors can incorporate into their products. The FHWA will continue to develop outreach and training course material for program delivery, training, and promotion. FHWA is also taking an active role in promoting more efficient transportation operations during hurricane evacuations. The FHWA is currently supporting an Evacuation Traffic Information System (ETIS), which is a web-based program that facilitates the sharing of evacuation and traffic information among states. In addition, the FHWA is investigating other Intelligent Transportation System technologies that can be used to support emergency and transportation managers during evacuations. Finally, the FHWA is researching how transportation operation centers around the country integrate weather information into their traffic management operations. The FHWA is interested in the types of information received (whether generic or tailored) and how that information impacts traffic management decisions. The FHWA is also investigating several other aspects of traffic management with respect to weather, including the modification of traffic signal timing, traffic modeling, and freeway operations in response to adverse weather.

United States Coast Guard (USCG)

All of USCG's funding for meteorological programs is for operations support. For FY 2002, 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 generating 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 2002 for directed meteorological research is $7.5 million which is $900,000 more than the FY 2001 funding level. This level was incremented in FY 2001 due to increased attention being paid to the effects 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 about $100 million in FY 2002. This augmented 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 2002 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $7.5 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 revisions to the National Ambient Air Quality Standards. Increased efficiency of computation and interpretation of results are being made possible by means of supercomputing 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 2002 is $155 million, which is nearly 6 percent lower than the FY 2001 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. In parallel with deploying EOS, NASA Earth Science Enterprise is looking ahead to determine what will be the important Earth science questions in the next decade, and which require NASA's leadership to be answered. Drawing on existing reports of the National Academy of Sciences and the state of progress in current scientific endeavors, ESE has developed a Research Strategy for 2000-2010. This strategy articulates a hierarchy of one overarching question, five broad subordinate questions and twenty- three detailed questions that can and should be tackled over this decade. For each, the Research Strategy defines the observational requirements, which in turn provide the basis for definition of candidate missions to be pursued. An early, high priority in this time frame is the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP), which will serve to provide continuity with the Terra and Aqua missions as well as a demonstration of instruments for the converged weather satellite program. NASA and the Integrated Program Office (IPO) jointly fund the NPP mission. The IPO consists of representation from the three agencies participating in NPOESS: NASA, the National Oceanic and Atmospheric Administration, and the Air Force. 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 a functioning data and information system to support the processing, archival, and distribution of data products from these missions. 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 request of $50,000 for FY 2002 is to continue assistance with the analysis of atmospheric dispersion for various potential release scenarios.

The meteorological support program in the NRC is focused primarily on obtaining and analyzing meteorological data to be used in atmospheric transport and dispersion models. These models serve to characterize plume pathways and project doses, and to estimate concentrations related to the safe operation of nuclear facilities. The intent is to protect the 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 as input to the assessment of the radiological impacts of routine airborne releases from facilities, and 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).

TABLE 2.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Operations Support FY2001	Operations Support FY2002	Systems Acquisition FY2001	Systems Acquisition FY2002	Special Programs FY2001	Special Programs FY2002	Total FY2001	Total FY2002	%CHG	% of FY2002 TOTAL
Agriculture	12600	12700	0	0	0	0	12600	12700	0.8	0.6
Commerce/NOAA(Subtot)	707896.2	743416	624829	726658	11776.3	15030	1344501.5	1485104	10.5	64.4
NWS	547783	574324	135542	141282	9505	12000	692830	727606	5.0	31.5
NESDIS	135712	141212	489287	585376	0	1200	624999	727788	16.4	31.5
OAR	3000	3124	0	0	0	0	3000	3124	4.1	0.1
NOS	12144.2	15056	0	0	728.3	730	12872.5	15786	22.6	0.7
NOAA Corps	9257	9700	0	0	1543	1100	10800	10800	0.0	0.5
Defense(Subtot)	281711	283763	126359	91505	796	841	408866	376109	-8.0	16.3
Air Force	123386	123590	65929	60937	0	0	189315	184527	-2.5	8.0
DMSP*	11185	12427	25139	12260	0	0	36324	24687	-32.0	1.1
Navy	123922	122464	875	904	0	0	124797	123368	-1.1	5.3
Army	23218	25282	34416	17404	796	841	58430	43527	-25.5	1.9
Interior/BLM	940	940	160	160	0	0	1100	1100	0.0	0.0
Transportation(Subtot)	322690.9	325051.8	124028.1	96162.4	7266.2	8029.5	453985.2	429243.7	-5.4	18.6
CG	6000	6000	0	0	0	0	6000	6000	0.0	0.3
FAA	316690.9	319051.8	124028.1	96162.4	7266.2	8029.5	447985.2	423243.7	-5.5	18.3
FHWA					------ Not Applicable ------					
EPA					------ Not Applicable ------					
NASA	2538	2257	231	450	703	138	3472	2845	-18.1	0.1
NRC	117	50	0	0	0	0	117	50	-57.3	0.0
TOTAL	1328493.1	1368177.8	875607.1	914935.4	20541.5	24038.5	2224641.7	2307151.7	3.7	100.0
% of FY TOTAL	59.7%	59.3%	39.4%	39.7%	0.9%	1.0%	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 FY2002 TOTAL
	FY2001	FY2002	FY2001	FY2002	FY2001	FY2002	FY2001	FY2002	%CHG	
Agriculture	15500	15500	0	0	0	0	15500	15500	0.0	4.0
Commerce/NOAA(Subtot)	71014	78883	12966	7334	18681.5	21615	102661.5	107832	5.0	27.7
NWS	11954	11954	11100	5460	0	0	23054	17414	-24.5	4.5
NESDIS	20172	24471	0	0	0	0	20172	24471	21.3	6.3
OAR	38888	42458	1866	1874	4340	4360	45094	48692	8.0	12.5
NOS	0	0	0	0	12872.5	15786	12872.5	15786	0.0	4.1
NOAA Corps	0	0	0	0	1469	1469	1469	1469	0.0	0.4
Defense(Subtot)	96702	70604	0	0	1123	875	97825	71479	-26.9	18.4
Air Force	42789	28467	0	0	0	0	42789	28467	-33.5	7.3
DMSP*	25139	12259	0	0	0	0	25139	12259	-51.2	3.1
Navy	12730	17893	0	0	0	0	12730	17893	40.6	4.6
Army	16044	11985	0	0	1123	875	17167	12860	-25.1	3.3
Interior/BLM					------ Not Applicable ------					
Transportation(Subtot)	27610.8	31432.5	0	0	230	150	27840.8	31582.5	13.4	8.1
CG					------ Not Applicable ------					
FAA	25110.8	28682.5	0	0	0	0	25110.8	28682.5	14.2	7.4
FHWA	2500	2750	0	0	230	150	2730	2900	6.2	0.7
EPA	6400	7500	0	0	0	0	6400	7500	17.2	1.9
NASA	111500	106500	54200	48900	0	0	165700	155400	-6.2	39.9
NRC					------ Not Applicable ------					
TOTAL	328726.8	310419.5	67166	56234	20034.5	22640	415927.3	389293.5	-6.4	100.0
% of FY TOTAL	79.0%	79.7%	16.1%	14.4%	4.8%	5.8%	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	
	FY2001	FY2002	FY2001	FY2002	FY2001	FY2002	FY2001	FY2002	FY2001	FY2002	FY2001	FY2002	FY2001	FY2002
Agriculture	0	0	0	0	0	0	12600	12700	0	0	0	0	12600	12700
Commerce/NOAA(Subtot)	1276861	1414348	35518	35596	29123	32036	0	0	0	0	3000	3124	1344501.5	1485104
NWS	641062	675760	35518	35596	16250	16250	0	0	0	0	0	0	692830	727606
NESDIS	624999	727788	0	0	0	0	0	0	0	0	0	0	624999	727788
OAR	0	0	0	0	0	0	0	0	0	0	3000	3124	3000	3124
NOS	0	0	0	0	12873	15786	0	0	0	0	0	0	12872.5	15786
NOAA Corps	10800	10800	0	0	0	0	0	0	0	0	0	0	10800	10800
Defense(Subtot)	21590	21343	263246	246396	36066	35653	0	0	81350	66178	6614	6539	408866	376109
Air Force	0	0	189315	184527	0	0	0	0	0	0	0	0	189315	184527
DMSP*	0	0	36324	24687	0	0	0	0	0	0	0	0	36324	24687
Navy	21590	21343	37065	36640	36066	35653	0	0	23462	23193	6614	6539	124797	123368
Army	0	0	542	542	0	0	0	0	57888	42985	0	0	58430	43527
Interior/BLM	0	0	0	0	0	0	1100	1100	0	0	0	0	1100	1100
Transportation(Subtot)	0	0	447985	423244	6000	6000	0	0	0	0	0	0	453985.2	429243.7
CG	0	0	0	0	6000	6000	0	0	0	0	0	0	6000	6000
FAA	0	0	447985	423244	0	0	0	0	0	0	0	0	447985.2	423243.7
FHWA							----- Not Applicable -----							
EPA							----- Not Applicable -----							
NASA	0	0	0	0	0	0	0	0	0	0	3472	2845	3472	2845
NRC	117	50	0	0	0	0	0	0	0	0	0	0	117	50
TOTAL	1298568	1435741	746749	705236	71189	73689	13700	13800	81350	66178	13086	12508	2224641.7	2307151.7
% of FY TOTAL	58.4%	62.2%	33.6%	30.6%	3.2%	3.2%	0.6%	0.6%	3.7%	2.9%	0.6%	0.5%	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 FY2001	Basic Meteorology FY2002	Aviation FY2001	Aviation FY2002	Marine FY2001	Marine FY2002	Agriculture & Forestry FY2001	Agriculture & Forestry FY2002	General Military FY2001	General Military FY2002	Other FY2001	Other FY2002	Total FY2001	Total FY2002
Agriculture	0	0	0	0	0	0	15500	15500	0	0	0	0	15500	15500
Commerce/NOAA(Subtot)	88164	90421	1625	1625	12872.5	15786	0	0	0	0	0	0	102661.5	107832
NWS	23054	17414	0	0	0	0	0	0	0	0	0	0	23054	17414
NESDIS	20172	24471	0	0	0	0	0	0	0	0	0	0	20172	24471
OAR	43469	47067	1625	1625	0	0	0	0	0	0	0	0	45094	48692
NOS	0	0	0	0	12872.5	15786	0	0	0	0	0	0	12872.5	15786
NOAA Corps	1469	1469	0	0	0	0	0	0	0	0	0	0	1469	1469
Defense(Subtot)	5906	5924	42859	28537	12730	17893	0	0	36230	19125	100	0	97825	71479
Air Force	0	0	42789	28467	0	0	0	0	0	0	0	0	42789	28467
DMSP*	0	0	0	0	0	0	0	0	25139	12259	0	0	25139	12259
Navy	0	0	0	0	12730	17893	0	0	0	0	0	0	12730	17893
Army	5906	5924	70	70	0	0	0	0	11091	6866	100	0	17167	12860
Interior/BLM							------ Not Applicable ------							
Transportation(Subtot)	0	0	25110.8	28682.5	0	0	0	0	0	0	2730	2900	27840.8	31582.5
CG							------ Not Applicable ------							
FAA	0	0	25110.8	28682.5	0	0	0	0	0	0	0	0	25110.8	28682.5
FHWA	0	0	0	0	0	0	0	0	0	0	2730	2900	2730	2900
EPA	0	0	0	0	0	0	0	0	0	0	6400	7500	6400	7500
NASA	0	0	0	0	0	0	0	0	0	0	165700	155400	165700	155400
NRC							------ Not Applicable ------							
TOTAL	94070	96345	69594.8	58844.5	25602.5	33679	15500	15500	36230	19125	174930	165800	415927.3	389293.5
% of FY TOTAL	22.6%	24.7%	16.7%	15.1%	6.2%	8.7%	3.7%	4.0%	8.7%	4.9%	42.1%	42.6%	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.

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 62.2 percent; aviation 30.6 percent; marine 3.2 percent; agriculture/ forestry 0.6 percent; general military services 2.9 percent; and other specialized services accounting for 0.5 percent. Table 2.5 shows the distribution of supporting research funds among the services with basic meteorology receiving 24.7 percent, aviation 15.1 percent, marine 8.7 percent, agriculture and forestry 4.0 percent, general military 4.9 percent, and the remaining 42.6 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.

PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 2.6 depicts agency staff resources in meteorological operations. The total agency staff resources requested for FY 2002 is 14,410. This total represents an increase of 0.6 percent from FY 2001.

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

AGENCY	FY 2001	FY 2002	% CHANGE	% of FY 2002 TOTAL
Agriculture	104	105	1.0	0.7
Commerce/NOAA (Subtotal)	5,742	5,767	0.4	40.0
NWS	4,659	4,681	0.5	32.5
NESDIS	883	883	0.0	6.1
OAR	32	32	0.0	0.2
NOS	114	114	0.0	0.8
NOAA Corps	54	57	5.3	0.4
Defense	4,944	4,979	0.7	34.6
Air Force (Subtotal)	3,266	3,266	0.0	22.7
Air Force Weather	3,201	3,201	0.0	22.2
DMSP	65	65	0.0	0.5
Navy	1,423	1,412	-0.8	9.8
Army	255	301	15.3	2.1
Interior (Subtotal)	12	12	0.0	0.1
BLM	8	8	0.0	0.1
Reimbursed**	4	4	0.0	0.0
Transportation (Subtotal)	3,517	3,546	0.8	24.6
FAA	3,431	3,459	0.8	24.0
FHWA	1	2	50.0	0.0
USCG	85	85	0.0	0.6
EPA	0	0	0.0	0.0
NASA	0	0	0.0	0.0
NRC	1	1	0.0	0.0
TOTAL	14,320	14,410	0.6	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 2002. 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 $365.4 million to NASA for procurement and launches of polar-orbiting ($114.1 million) and geostationary ($251.3 million) satellites.

Department of Defense. The Air Force will reimburse DOC a total of $4.3 million for operations [OFCM support ($140,000), Lightning Data ($551,000), NCEP operations ($12,000), and Shared Processing Network ($193,000)] and supporting research [OAR laboratories ($170,000), Environmental Scenario Generator ($613,000), and NEXRAD ($2.62 million)]. In addition, DOE will receive $484,000 for Argonne Laboratories supporting research; NSF will receive $190,000 for COMET participation and $323,000 for NCAR supporting research. The Navy will reimburse DOC $214,000 for basic climatological analysis and forecasting, and interagency coordination. The Army reimbursements to DOC/NOAA include $770,000 to NWS for maintaining precipitation reporting stations and $290,000 to NOAA laboratories for precipitation modeling and basic/applied research. The Army will also reimburse the AF Air Combat Command $56,000 for operations and maintenance of weather systems and $110,000 for purchase of Tactical VSAT equipment. Finally, the United States Geological Survey will be reimbursed $379,000 for operations and maintenance of hydrologic and precipitation reporting stations.

Department of Transportation. The FAA will reimburse NOAA almost $32.8 million in FY 2002. Included in those funds are development of enhancements and operational support associated with the WSR-88D, 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 the Army a total of $195,000, the Navy $683,000, and Air Force $2.572 million for supporting research. The NOAA will receive $7.9 million for various supporting research associated with aeronautical hazards mitigation. The NASA will receive $550,000 for supporting research.

National Aeronautics and Space Administration (NASA). The Air Force will be reimbursed a total of $2.841 million--$2.091 million for observations, forecasts, and operations/maintenance of weather infrastructure and replacement of upper air systems at Trans-Atlantic Abort Landing Sites and $750 million for technology transition at Applied Meteorology Unit, Eastern Range. NOAA's NWS will receive $16,000 for upper air analysis and research; National Data Buoy Center will receive reimbursements of $92,000 for the operation of two data buoys.

Environmental Protection Agency (EPA). NOAA's Air Resources Laboratory (ARL) will receive $6 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 2001 Funds ($K) Estimated or Planned Operations	Supporting Research
Commerce/NOAA	DOT/USCG	2.5	
	NASA Studies	60	
	NASA	365,416	
Defense/Air Force	DOC/NOAA/OFCM	140	
	DOC/NOAA/LDS	551	
	DOC/NOAA/NCEP	12	
	DOC/NOAA/SPN	193	
	DOC/NOAA/OAR		170
	DOC/NOAA/ESG		613
	DOC/NOAA/NWS		2619
	DOE/Argonne		484
	NSF/NCAR		323
	NSF/COMET		190
Defense/Navy	DOC/NOAA/NCDC	49	
	DOC/NOAA/OFCM	165	
Defense/Army	DOC/NOAA/NWS	770	
	DOC/NOAA/ETL		65
	DOC/NOAA/ATDD		75
	DOC/NOAA		150
	DOI/USGS	379	
	DOD/USAF/ACC	166	
Transportation/FAA	DOC/NOAA	24,839	7,942
	DOD/USA		195
	DOD/USAF		2,572
	DOD/USN		683
	NASA		550
NASA	DOD/USAF	2,091	750
	DOC/NOAA/NDBC	92	
	DOC/NOAA/NWS		16
EPA	DOC/NOAA/ARL		6,000
NRC	DOE/PNNL	87	

TABLE 2.8 FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

TYPE OF OBSERVATION/AGENCY	No. of Locations (FY 2001)
Surface, land	
Commerce (all types)	841
Air Force (U.S. & Overseas)	130
Navy (U.S. & Overseas)	34
Army (U.S. & Overseas)	34
Marine Corps (U.S. & Overseas)	13
Transportation (Flight Service Stn)	8
Transportation (Lim Aviation Wx Rptg Stn)	114
Transportation (Contract Wx Obsg Stn)	189
Transportation (Auto Wx Obsg Stn)	198
Transportation (Auto Sfc Obsg Sys, fielded)	569
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	287
Transportation (USCG Cutters)	225
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	97
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	1
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	10
Marine Corps	9
Transportation	25
NASA	2
Airport terminal Doppler weather radars	
Transportation (Commissioned)	45
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
Polar meteorological satellites (No. operating)	
Commerce (planned config of 2)	2
Air Force	4
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 warnings and forecasts 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.

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 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.

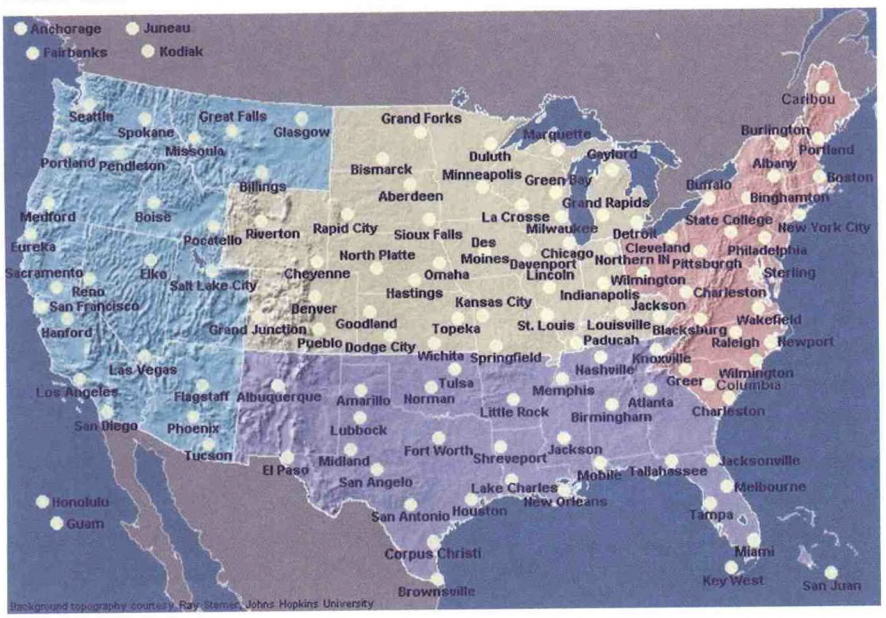


Figure 3-DOC-1. Locations of NWS Weather Forecast Offices.

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.

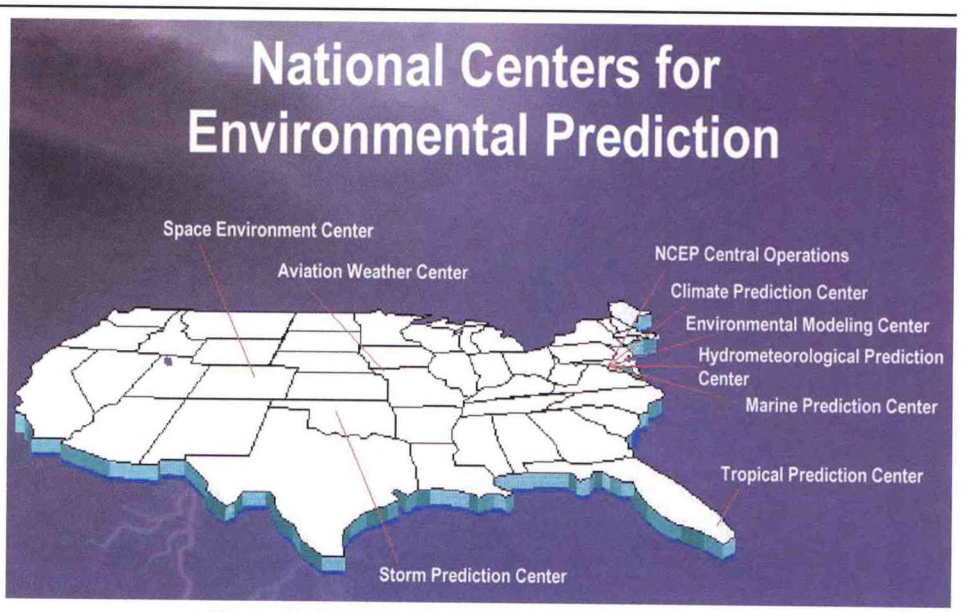


Figure 3-DOC-2. Locations of NCEP centers.

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 (Figure 3-DOC-3).

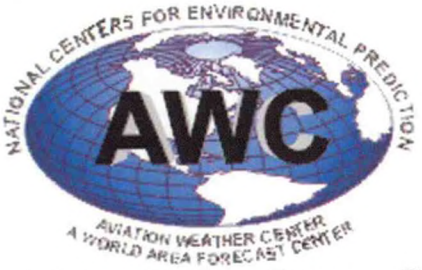
Marine Prediction Center. The Marine Prediction Center (MPC) handles United States international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). This center provides one-stop-shopping for marine interests operating outside the domain 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,

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.
- 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 multisensor 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.

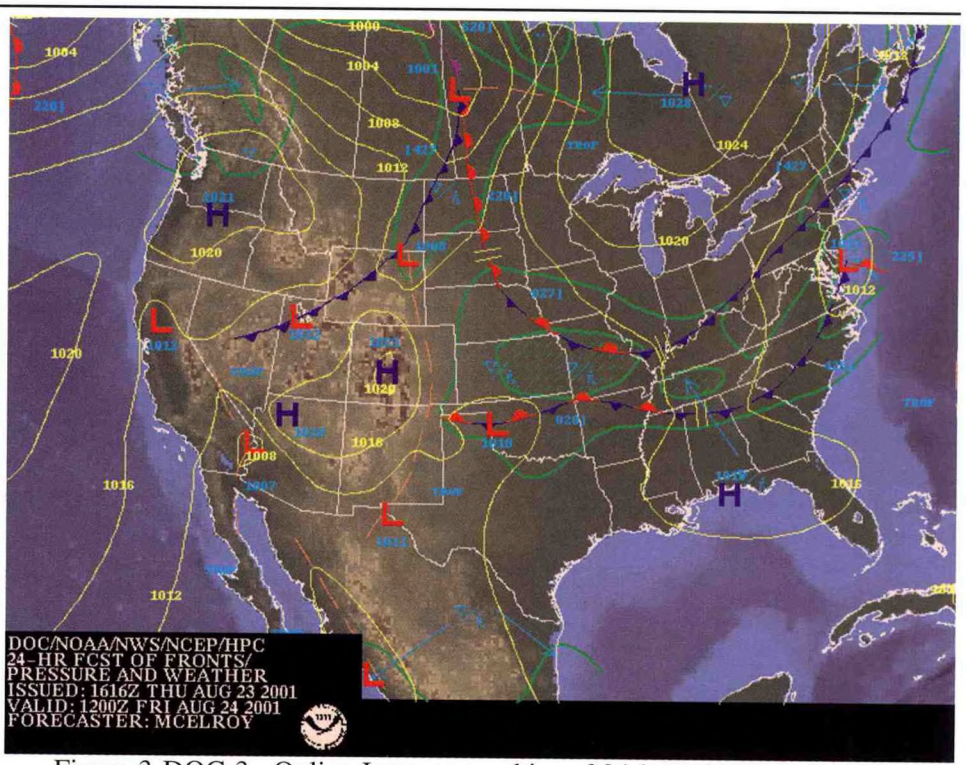


Figure 3-DOC-3. Online Internet graphics of 24-hour forecast depicting weather fronts, pressure systems, and weather issued by the NWS Hydrometeorological Prediction Center.

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 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-4).

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

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 2005. Thus, upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission.

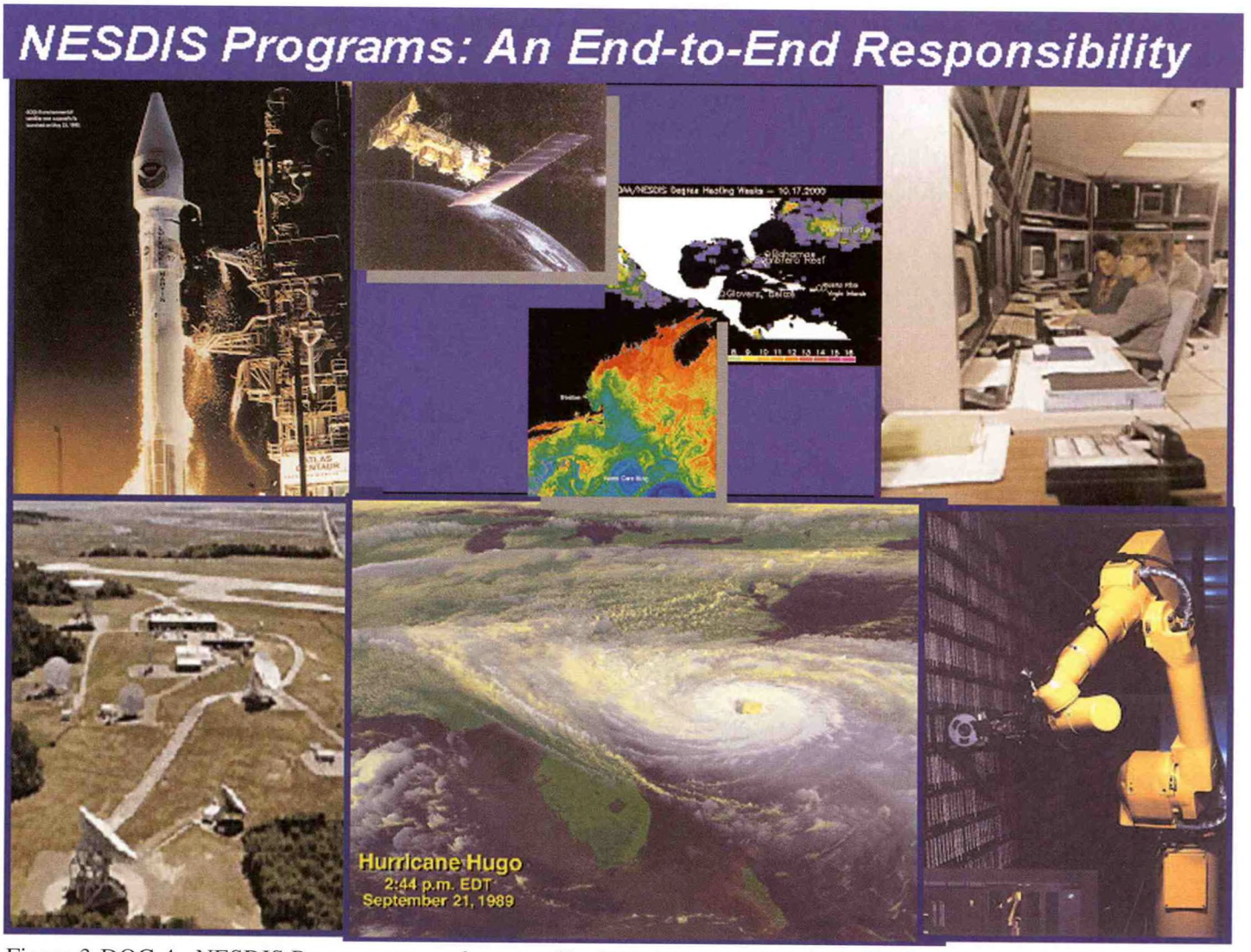


Figure 3-DOC-4. NESDIS Programs range from satellite launch to operational monitoring to data communications and archiving.

On October 3, 1994, NOAA, the Department of Defense (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 overall program plans also meet the individual 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 late in this decade depending on when the current NOAA and Defense Meteorological Satellite Program (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

Office of Satellite Operations

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 DMSP constellation in 1998. The mission of DMSP is to provide meteorological and special sensor data to users in support of worldwide 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.

Office of Satellite Data Processing and Distribution

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 and GOES scheduling.

Satellite sources include the European, Japanese, and Indian operational geostationary satellites (METEOSAT, GMS, and INSAT respectively) and other research or experimental sources, such as the NASA's Tropical Rainfall Measuring Mission (TRMM) and Japan's ADEOS. OSDPD processes and distributes these NOAA and non-NOAA environmental satellite products to the NWS National Centers and Weather Forecast Offices (WFOs), and other federal, state, and private sector organizations through dedicated satellite server configurations, or through the NOAAPORT satellite point-to-point broadcast facility.

Data for NOAAPORT are remapped digital data satellite products and derived products, such as lifted index, high density wind direction and intensities at various atmospheric levels, quantitative precipitation estimates, and volcanic ash advisory messages. NOAAPORT delivers GOES and soon to be added POES products in virtual real-time to the Advanced Weather Interactive Processing System (AWIPS). AWIPS is the NWS's new display and analysis workstation used in their national centers and field sites to integrate and display satellite data, model data, observations, radar and wind profiles for hydrometeorological

analyses. As the AWIPS satellite capabilities improve, NESDIS will shift focus from support of the RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS). RAMSDIS currently supplies digital GOES and POES images to a group of NWS sites 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 it's support of the COSPAS-SARSAT Program through provision of satellites, ground stations, and alert data distribution services. The COSPAS-SARSAT program consists of Russia, the United States, France, and Canada providing the space segment and 29 other countries providing ground systems to relay distress alerts or participate in the management of the program. NESDIS operates and maintains the United States SARSAT Mission Control Center and fourteen ground stations.

The ground stations receive signals directly from the satellites and process the information to provide the location of distress transmissions (Figure 3-DOC-5). In 2000, COSPAS-SARSAT decided to terminate satellite processing of 121.5/243 MHz signals beginning February 1, 2009. This decision was made in response to guidance from the International Civil Aviation Organization and the International Maritime Organization. These two specialized agencies of the United Nations are responsible for aviation and maritime search and rescue. The use of new emergency beacons that can use the Global Positioning System (GPS) to provide an accurate position continues to increase. Seven of the last fourteen 406 MHz beacon models approved are able to use GPS to transmit their position.

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 the highest quality operational global, regional, and tactical scale sea ice analyses and forecasts, tailored to meet the requirements of United States National interests. NIC ice 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. 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. RADARSAT's ScanSAR wide mode produces a 500km wide swath with 100m spatial resolution. Images are processed at four different 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 working on the transition of real-time SSMI sea ice products to the NIC

Figure 3-DOC-5. United States Coast Guard rescue helicopter locates crew of capsized trimaran with information provided by SARSAT.

operations floor, conducting an evaluation of current SSM/I-derived sea ice algorithms, and the use of SSM/I data for initializing and evaluating the Polar Ice Prediction System (PIPS).

Routine NIC ice guidance products include regional-scale ice maps, annotated satellite imagery; short and long-term ice forecasts, and legacy ice information and ice climatology. Specialized support services include specific regional support, ship route recommendations, pre-sail ship briefings, aerial ice reconnaissance, and ship rider support. Specific sea ice features analyzed 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 disseminated via the Internet (*www.natice.noaa.gov*) as simple electronic charts in Joint Photographic Experts Group (JPEG format), GIS-compatible coverages (ESRI ARC/INFO .e00 export format), and in the World Meteorological Organization (WMO) digital standard for Sea Ice in GRIDded (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 the NIC's responsibilities is oversight of the United States Interagency Arctic Buoy Program (USIABP). The USIABP was established in 1992 to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields (Figure 3-DOC-6). 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 seven govern-

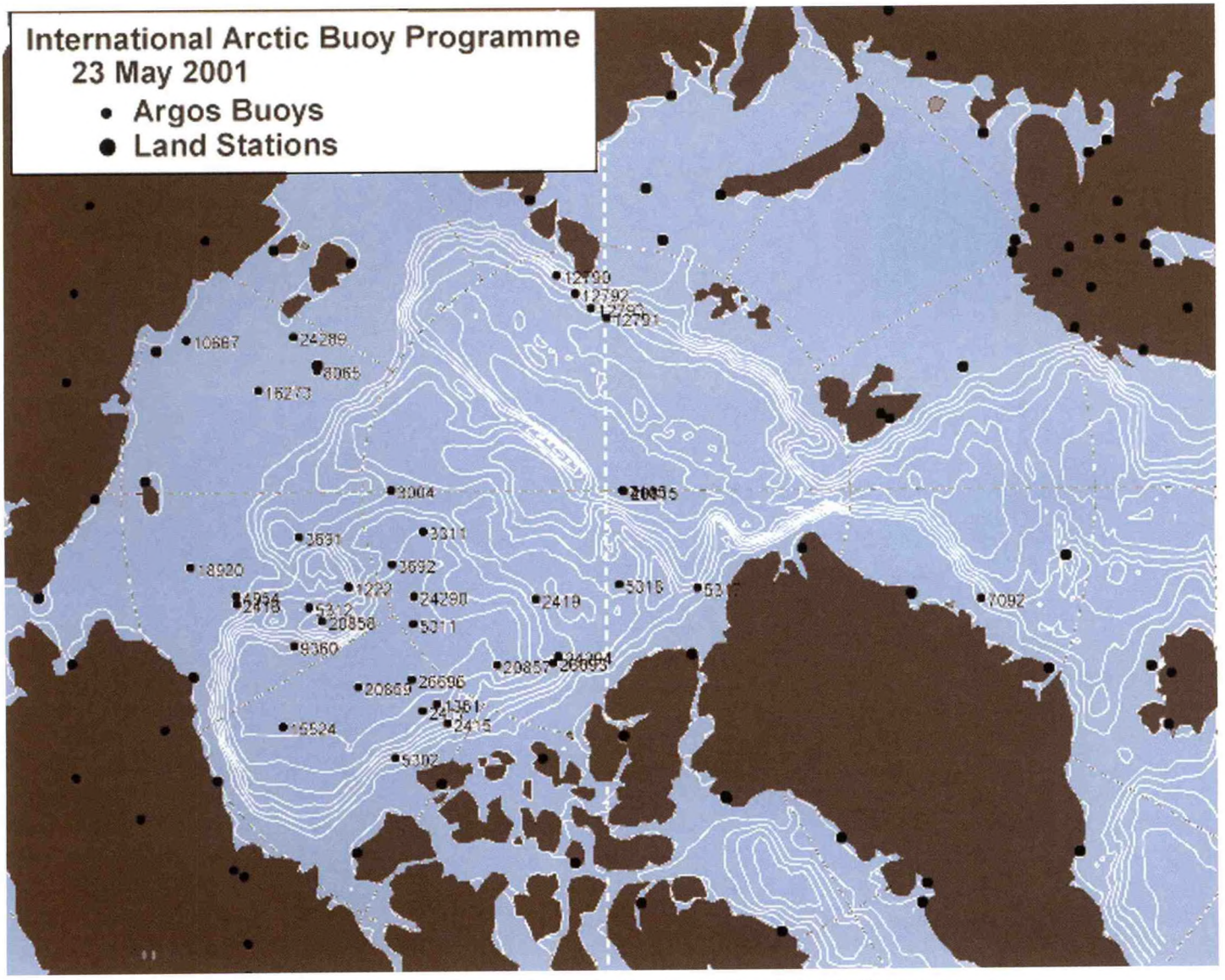


Figure 3-DOC-6. Locations of buoys in the International Arctic Buoy program.

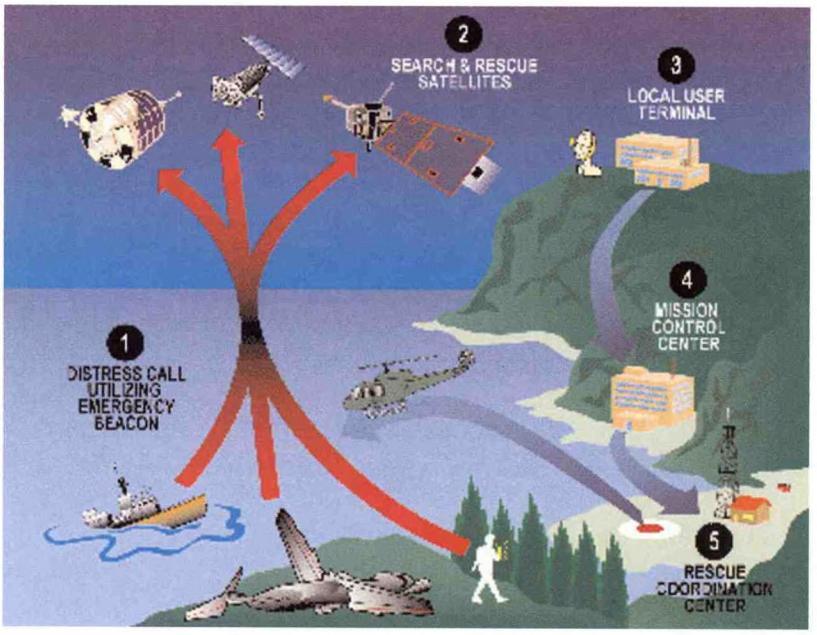
ment agencies and/or programs. These organizations include: the Naval Oceanographic Office, Office of Naval Research (ONR), NASA, National Science Foundation (NSF), and NOAA's NESDIS, OAR, and Office of Global Programs (OGP).

Office of Research and Applications

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. Additionally, ORA through division participation, actively educates others on technology transfer programs 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-16.



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.

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 long wave 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 long wave IR band that, 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° (48km on surface at nadir) and AMSU-B a field of view of 1.1° (16km on surface at nadir). AMSU-A (AMSU-B) samples 30° (90°) Earth views, covering ±48.95° from the subsatellite 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 NOAA-16 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 that 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 operational meteorological services (Figure 3-DOC-7). 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. Also, the resolution of the water vapor channel will improve to 4km from 8km.

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.

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM		GEOSTATIONARY SYSTEM	
Satellite Designator	Planned Launch Date*	Satellite Designator	Planned Launch Date*
NOAA M	CY 2001	GOES M	CY 2001
METOP-1	CY 2005	GOES N	CY 2002
NOAA-N	CY 2004	GOES O	CY 2005
NOAA-N'	CY 2008	GOES P	CY 2007
METOP-2	CY 2010	GOES Q	CY 2010
METOP-3	CY 2012	GOES R	CY 2012
NPOESS-3	CY 2014		
NPOESS-4	CY 2016		
NPOESS-5	CY 2018		

*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

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 7fi-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 online 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 gauges, 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 communi-

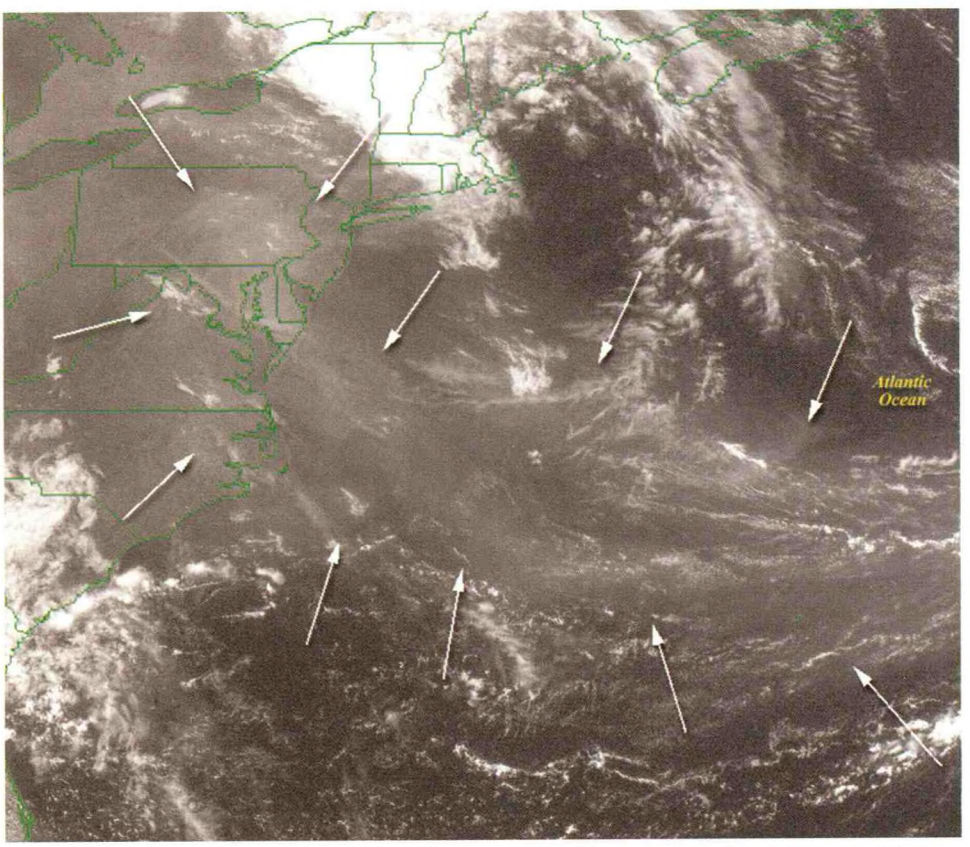


Figure 3-DOC-7. Smog (indicated by the white arrows) is visible in this GOES-8 image stretching from the East Coast over the Atlantic Ocean.

cations 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 sectorized images, mapped to standard AWIPS grids, available in near-real-time at *www.goes.noaa.gov*. Near-real-time images and interpretive analyses of tropical storms and hurricanes worldwide, ash from volcanic eruptions within the western hemisphere, heavy precipitation in the United States which cause flash flooding or blizzards, wildland fires and smoke within the United States, and northern hemisphere snow boundaries are located at *www.ssd.noaa.gov*. Specially enhanced and annotated imagery and image loops of environmental events, such as flooding, hurricanes and other severe storms, volcanic eruptions, fires, and dust storms are available from *www.osei.noaa.gov* (Figure 3-DOC-7). This web site was set up for use by the news media, general public and to provide once or twice per day satellite views of an environmental event for federal, state, and international governments and agencies. Also supporting the media, scientific organizations, and federal and state agencies is a specially designed web site featuring visualizations of satellite data, found at *www.nnvl.noaa.gov/*.

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 (*www.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. The NESDIS GOES winds processing suite is totally automated and uses a series of geostationary satellite images to derive wind estimates. 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. The automated quality control of image registration is also an important component of the NESDIS GOES winds processing suite. 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.* Digital sounding and winds files are available through a GOES computer server within OSDPD.

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 that presently have a horizontal resolution of approximately 50km^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.* Digital versions of these products are available from POES and GOES computer servers within OSDPD. A similar suite of products is being developed from NOAA-14 and NOAA-15 for forecasters.

Tropical Cyclone Monitoring

NESDIS continues to improve upon satellite-based techniques for estimating tropical cyclone positions and intensities, and for describing the internal structure of these storms. New sensors such as AMSU, TRMM among others are being incorporated into the NESDIS operational tropical program, which supports the NWS and DOD hurricane programs. Real-time imagery and NESDIS tropical text messages can be viewed at *www.ssd.noaa.gov/SSD/ML/realtime. html.*

Precipitation Estimates

The Auto-Estimator produces quarter-hourly estimates of precipitation based on GOES infrared data. This technique was designed to eventually replace the more manual "Interactive Flash Flood Analyzer" (IFFA), but currently both techniques are used to produce the best quality product for NWS. 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 an inter-comparison 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 (Figure 3-DOC-8) 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 at *manati.wwb.noaa.gov/doc/ssmi-precip.html*. Digital versions of these products are also available from POES and GOES computer servers within OSDPD.

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 (10.7µm and 3.9µm) 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 long wave infrared (12.0µm) 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

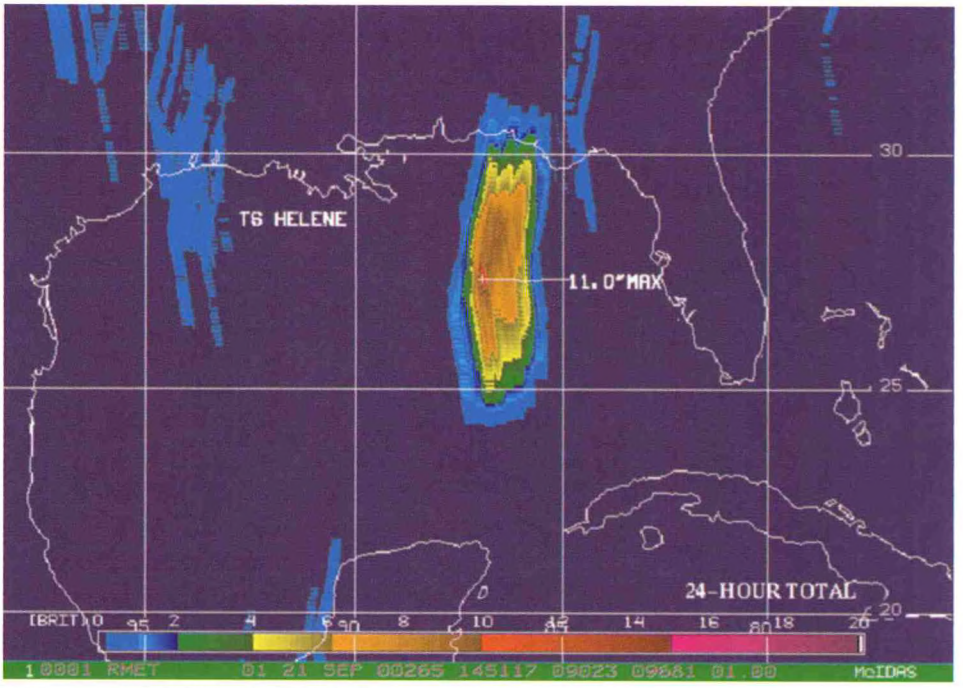


Figure 3-DOC-8. GOES infrared data were used to prepare 24-hour rainfall potential estimates for Tropical Storm Helene.

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. Additionally, a change in scene temperature over a short period of time may indicate the presence of clouds, thereby enhancing cloud detection. 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 in an experimental configuration since December 1998 for both GOES-8 and GOES-10. A global SST product is produced every three hours; regional SST products are generated every hour. These products were recently implemented operationally and can be accessed as digital files from the GOES computer servers within OSDPD.

Volcanic Ash and Fire Monitoring

Techniques that use primarily the imager channels on GOES-East/West are being developed to assist in the tracking of volcanic ash cloud plumes. 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 (VAAC) in Washington, District of Columbia. Experimental volcanic ash products are produced hourly for several active volcanic areas and are available at *orbit-net.nesdis.noaa.gov/arad/fpdt/volc.html*. GOES infrared, visible, NASA's Total Ozone Mapping Spectrometer (when applicable), and operational volcanic ash products for the Washington VAAC area of responsibility are found at *www.ssd.noaa.gov/VAAC/washington.html*. An emphasis is being placed on development and testing of sounder and other techniques that do not use

the GOES 12 micron channel since the next GOES spacecraft, GOES-M, will not carry this channel.

Fire and smoke monitoring algorithms are being developed to automatically 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 7fi minutes) can assist firefighters to plan evacuation and extinguishing activities. 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. All these new techniques will be used to improve the current operational fire and smoke product, currently posted to the Internet at *www.ssd.noaa.gov/ssdfire.html*. This product supports the NWS Storm Prediction Center (SPC) fire outlook product. Real time imagery of GOES and POES imagery in support of SPC can be found at *www.ssd.noaa.gov/SAB/SPECIAL/ID/id?fires.html*.

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. The Polar Products and Services Catalog is under development.

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 took place for the new Solar Backscatter Ultraviolet Instrument (SBUV/2) with the launch and successful checkout of NOAA-16. 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, NOAA-14, and NOAA-16, and with the TOVS instruments on NOAA-14, NOAA-15 and NOAA-16. 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 Environment Service, Canada for evaluation. New techniques such as automatic edge detection and incorporation of new sensors such as AMSU and NASA's MODIS are in development to improve operational production of daily snow and ice extent products. These products are delivered as digital files to NWP models and to the NWS Climate Prediction Center and other users. Graphical imagery of operational northern hemispheric snow cover can be found on the Internet at *www.ssd.noaa.gov/SSD/ML/realtime.html#SNOW*.

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 the evaluation of new algorithm and instrument designs that 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. NASA's Clouds from the Earth's Radiant Energy System (CERES) instrument data processing team apply this correction algorithm, to VIRS raw data prior to application of the NESDIS operational aerosol retrieval algorithm. 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. This algorithm is also applied to NOAA-16 AVHRR data that 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 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. NOAA will 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 interna-

tional 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.

Calibration of Geostationary Operational Environmental Satellite Instruments

The wavelength configuration of channels on the GOES-M Imager will be slightly different from that of its predecessors. A 13.3µm channel will replace the current 12µm channel. 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 observe 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. The analysis of time series of anomalies of the cloud radiative forcing has been shown to correlate well (spatially and temporally) 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 would 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. 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 *in situ* 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 locations of many coral reefs preclude normal monitoring practices. In 1998, NESDIS established an experimental capability (Figure 3-DOC-9) using POES satellites to conduct thermal bleaching surveillance of coral reefs on a world-wide 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. In 2001 NESDIS will implement satellite reef health monitoring into its operation.

CoastWatch

NESDIS has responsibility for CoastWatch Program Management. This program managed in conjunction with other NOAA Line Offices makes satellite data products and *in situ* data from NOAA environmental buoys available to federal, state, and local marine scientists and coastal resource managers.

For coastal areas in the Great Lakes, East Coast, and Gulf of Mexico, data from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA's polar orbiting spacecraft are collected at Wallops Island, Virginia, and at Fairbanks, Alaska. These data are processed on NOAA computers in Suitland, Maryland using a set of NOAA-developed multi-channel atmospherically corrected algorithms for determination of sea surface temperature. Data are then mapped (Mercator Projection) and sectored to predefined coordinates specified for each of the CoastWatch regions. Digital, high-resolution data products (1 km/4 km in a CoastWatch Binary Format) are then passed daily to CoastWatch Regional Nodes in the eastern United States (i.e., Southeast, Great Lakes, Northeast, Gulf of Mexico, and Caribbean). For Regional Nodes in the Pacific region CoastWatch local data acquisition and processing capabilities are in La Jolla, California; Anchorage, Alaska; and Honolulu, Hawaii.

The Internet is used as the primary telecommunications pathway for digital data distribution. Once products are delivered to the CoastWatch Regional Nodes they become immediately available for local use (Figure 3-DOC-10). An ever-growing number of federal, state, and local organizations are establishing a formal relationship with local CoastWatch Regional Nodes for routine timely access to CoastWatch image products. More information about CoastWatch is available on the Internet at *coastwatch.noaa.gov/COASTWATCH/.*

ENVIRONMENTAL DATA CENTERS

NESDIS is responsible, among other things, for the collection, archiving, and dissemination of environmental data collected by a variety of *in situ* and remote sensing observing systems from throughout NOAA and from a number of its partners, (e.g., NASA). NESDIS must have a Comprehensive Large

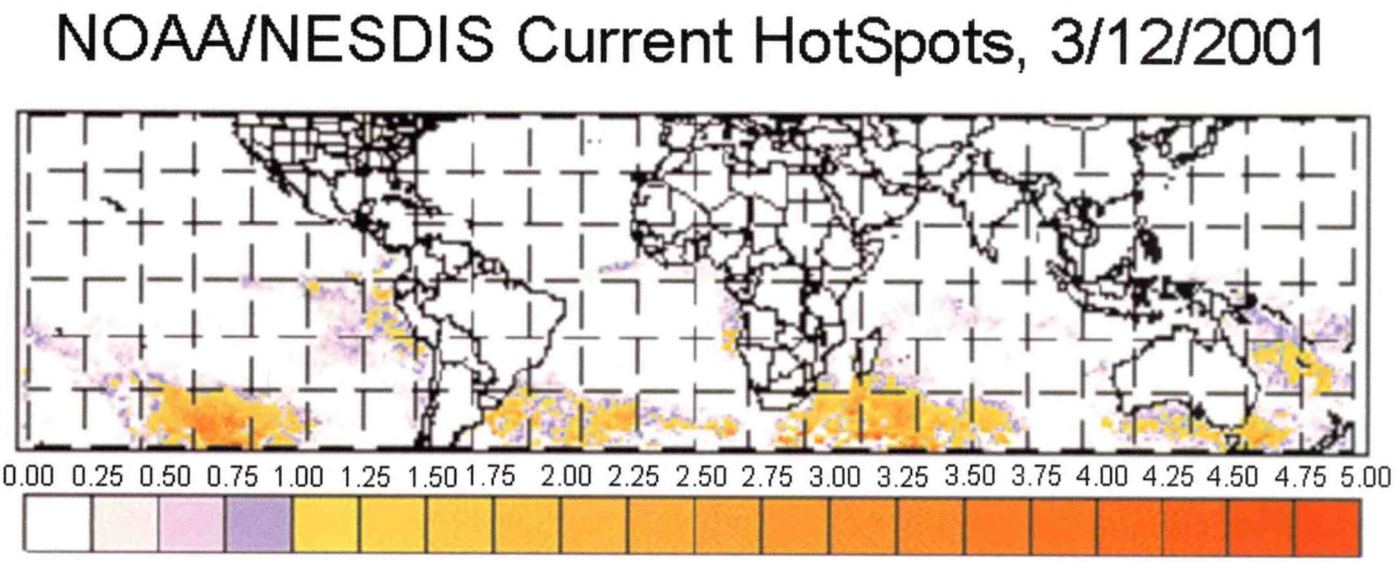


Figure 3-DOC-9. NESDIS satellites monitor the health of coral reefs.

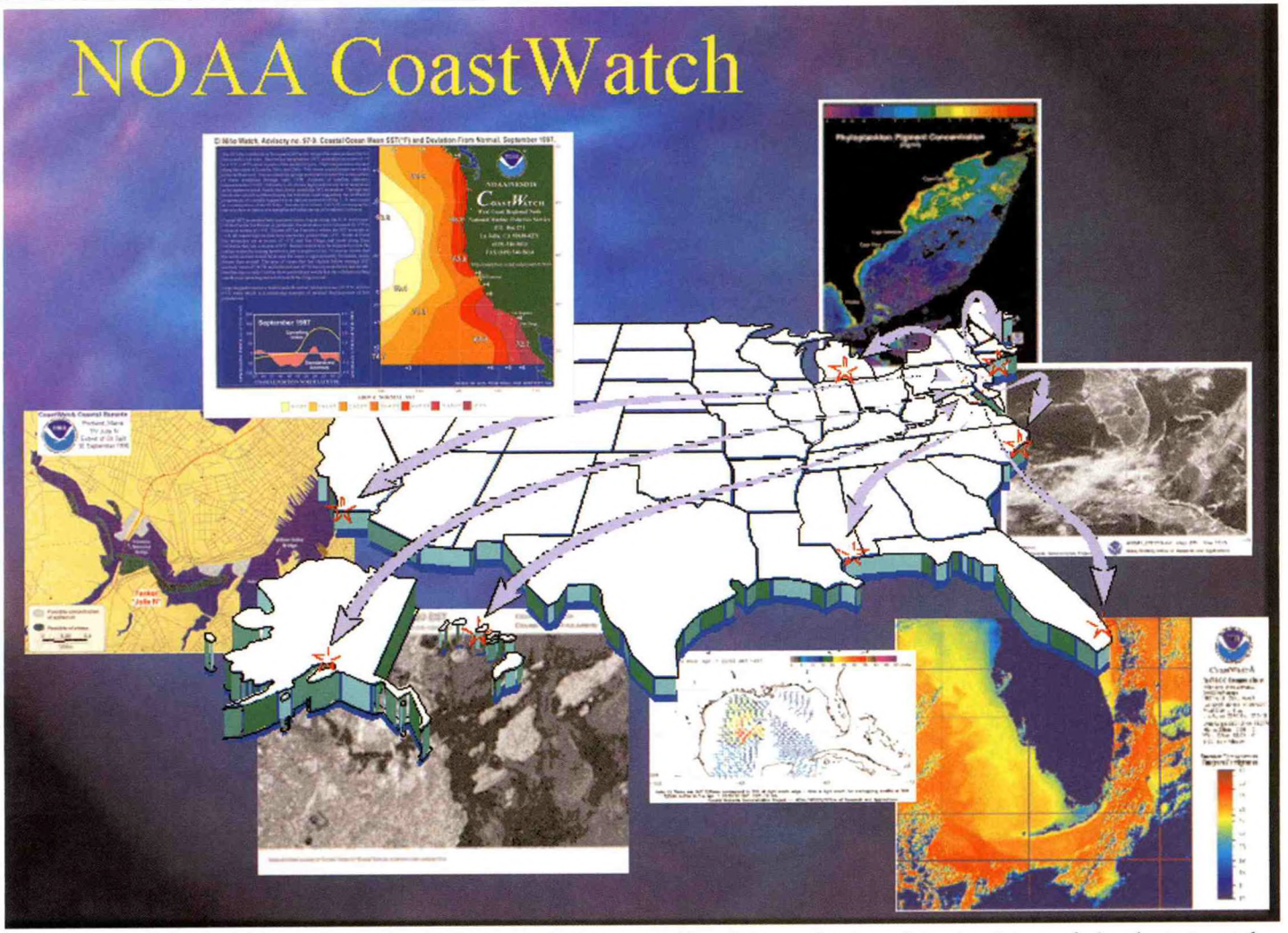


Figure 3-DOC-10. NOAA CoastWatch Program delivers satellite data products and *in situ* data to federal, state, and local marine scientists and coastal resource managers.

Array-data Stewardship System (CLASS) that provides archive and access services for these data in place by December 2002. CLASS will be able to handle the data flow from current satellite-based (e.g., GOES, Defense Meteorological Satellite Program - DMSP) and ground-based (e.g., Next Generation Weather Radar - NEXRAD, Automated Surface Observing System - ASOS) observing systems, and be structured to handle the large increases in data that will come from planned satellite launches, beginning with the first of the Meteorological Operational satellites (METOP-1), and followed in ensuing years by additional satellite launches [e.g., National Polar-orbiting Operational Environmental Satellite System (NPOESS), NPOESS Preparatory Project (NPP), and Earth Observing Satellites (EOS)].The first EOS satellite (Terra) has been launched and NOAA and NASA are presently negotiating a Long Term Archive agreement for the safeguarding of EOS data. Some of these data may flow to NESDIS before the launch of METOP-1. The December 2002 date is key to the initiation of the period during which NOAA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) will begin to share data from the EUMETSAT METOP-1 launch in July 2003. CLASS will be able to ingest, catalog, quality control, archive, and, via e-commerce, make available to NESDIS' customers and partners (e.g., NASA) the satellite, radar, and other *in situ* environmental information and data sets contained in the system.

NATIONAL CLIMATIC DATA CENTER

The National Climatic Data Center (NCDC) (*www.ncdc.noaa.gov*) has the responsibility for long-term stewardship of 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 meteorologi-

cal 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 Aeronautics and Space Administration (NASA), Department of Defense (DOD), Environmental Protection Agency (EPA), United States Department of Agriculture (USDA), Department of Energy (DOE), Department of State (DOS), National Science Foundation (NSF), United States Geological Survey (USGS), United States Global Climate Research Panel (USGCRP), and others.

• NCDC partners internationally with: World Meteorological Organization, International Council of Scientific Unions (ICSU), World Data Centers, other nations via bilateral agreements, Intergovernmental Panel on Climate Change, UNESCO.

• NCDC maintains and updates national and global baseline data sets for analyses of long-term climate trends and for monitoring global change. These data sets include the Global Historical Climatology Network (GHCN), the United States Historical Climatology Network (USHCN), the Comprehensive Ocean-Atmosphere Data Set (COADS), and the Comprehensive Aerological Reference Data Set (CARDS).

• NCDC serves as World Data Center-A (WDC-A) for Meteorology under the auspices of the International Council of Scientific Unions. In this capacity, NCDC archives the data collected by internationally sponsored research programs and actively exchanges climate data with foreign countries.

• NCDC provides facilities, data processing support, data exchange, and expertise, as required, to meet United States commitments to foreign nations, international organizations, and to the World Meteorological Organization's (WMO) programs.

• 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 a vital component of a national climate services program.

SUPPORTING RESEARCH

Global Historical Climatology Network

The Global Historical Climatology Network (GHCN) data set on-line at *www.ncdc.noaa.gov/ol/climate/research/ghcn/ghcn.html* 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. NCDC is striving to move the continual updating of this data set into an operational scenario.

Global Blended Temperature Product

A global surface temperature data set is being operationally produced from numerous sources including sea surface temperatures (SST), land surface temperatures (GHCN) and satellite data using the Special Sensor Microwave Imager (SSMI) which collects data over land areas that are not snow covered.

New Climate Atlas of the United States

NCDC completed a new Climate Atlas of the United States and is distributing it via CD-ROM. The purpose of this new atlas is to depict the climate of the United States in terms of the distribution and variation of major climatic elements. The Climate Atlas meets 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 contains several hundred updated high resolution GIS generated maps.

Climate Reference Network Project

The United States Climate Reference Network (CRN) is a planned network of 250 climate stations now being developed as one component of the NOAA Climate Services Initiative. The primary goal of this network is to provide 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 of America 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. The first two CRN stations (primary and backup) were installed in the year 2000 and are operating near Asheville, North Carolina.

Climate Monitoring

The National Climatic Data Center's (NCDC) Climate Monitoring Branch 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 responds to high level NOAA and executive level governmental requests concerning the state of the national and global climate. NCDC also is producing for the first time in 2001 The Climate Assessment for the Year 2000, which will be published as a special issue of the *Bulletin of the American Meteorological Society*. There are national and international contributors to this effort from operational and research institutions, the university community and other NOAA components.

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.

NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (NODC) (*www.nodc.noaa.gov*) manages the world's largest collection of publicly available oceanographic data. NODC holdings include *in situ* and remotely-sensed physical, chemical, and biological oceanographic data from coastal and deep ocean areas. NODC customers reuse this data to answer questions about climate, and ocean and coastal phenomena. Specifically, NODC data archive and access responsibilities support climate research and operational activities as follows:

International

- NODC provides data management for major climate-related research programs including: Tropical Ocean Global Atmosphere (TOGA), World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), and Global Temperature Salinity Profile Program (GTSPP).
- NODC served as the Upper Ocean Thermal Data Assembly Center for WOCE, part of the World Climate Research Program. WOCE made unprecedented *in situ* and satellite observations of the global ocean between 1990 and 1998. NODC, in cooperation with WOCE, published this international data set on CD-ROM.
- NODC performs a number of functions for GTSPP (*www.nodc.noaa.gov/GTSPP/gtspp-home.html*), including incorporation of real-time and delayed mode data into a continuously managed database. GTSPP makes global temperature and salinity data quickly and easily accessible to users.
- NODC produces regular updates of the World Ocean Data Base (WOD) (*www.nodc.noaa.gov/OC5/pr_wodv2.html*) and World Ocean Atlas (WOA) (*www.nodc.noaa.gov/OC5/pr_woa.html*). WOD 1998, produced in 2000, includes over five million profiles of scientifically quality controlled ocean temperature, salinity, oxygen, plankton, pigment, and nutrient data. WOA 1998 presents statistical summaries and gridded fields of these parameters on a monthly, seasonal, and annual basis, from the 1940's through 1998.
- NODC distributes the *Atlas of Surface Marine Data* on CD-ROM. This atlas includes global surface marine observations taken from COADS (Comprehensive Ocean-Atmosphere Data Set) files, and objectively gridded fields of surface marine fluxes of heat, momentum, and freshwater.

National

- The NOAA Marine Environmental Buoy Database (*www.nodc.noaa.gov/BUOY/buoy.html*) is one of the largest and most frequently used data archives maintained by the NODC. This database holds wind, wave, and other marine data collected by the NOAA National Data Buoy Center (NDBC) from moored buoys and C-MAN (Coastal-Marine Automated Network) stations. Parameters reported by both buoys and C-MAN stations include air temperature and pressure, wind speed and direction, wind gust, and sea surface temperature.
- NODC provided archive and store-and-forward data services in support of a National Ocean Partnership Program project to conduct tests of a coastal marine forecast system. The project was a collaboration between the National Ocean Service, the National Weather Service, several universities, and industry groups. NODC served as the central data exchange facility.
- NODC provides data products and services individually to members of the operational marine community, e.g., the Navy, Coast Guard, and shipping industry.
- NODC CD-ROM products are described on its web pages (*www.nodc.noaa.gov/General/NODC-cdrom.html*), and made available through the NOAA National Data Centers' (NNDC) Online Store.

NOAA/NODC Library

NODC houses the NOAA Central Library (*www.lib.noaa.gov/*) which supports weather and climate research programs by providing a variety of information services, including:

- Access to print and electronic versions of American Meteorological Society journals.
- Access to Meteorological and Geoastrophysical Abstracts (desktop access at the Silver Spring campus).
- Desktop access to Web of Science at several NOAA sites.

• Assistance in obtaining site licenses for 169 National Weather Service field sites for electronic access to Monthly Weather Review and Weather and Forecasting.

• Archival of historic collections of the Weather Bureau.

• Data rescue of hundreds of volumes of meteorological data publications in danger of loss.

NATIONAL GEOPHYSICAL DATA CENTER

The National Geophysical Data Center (NGDC) (*www.ngdc.noaa.gov*) 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 (Figure 3-DOC-11). 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 of Scientific Unions. 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

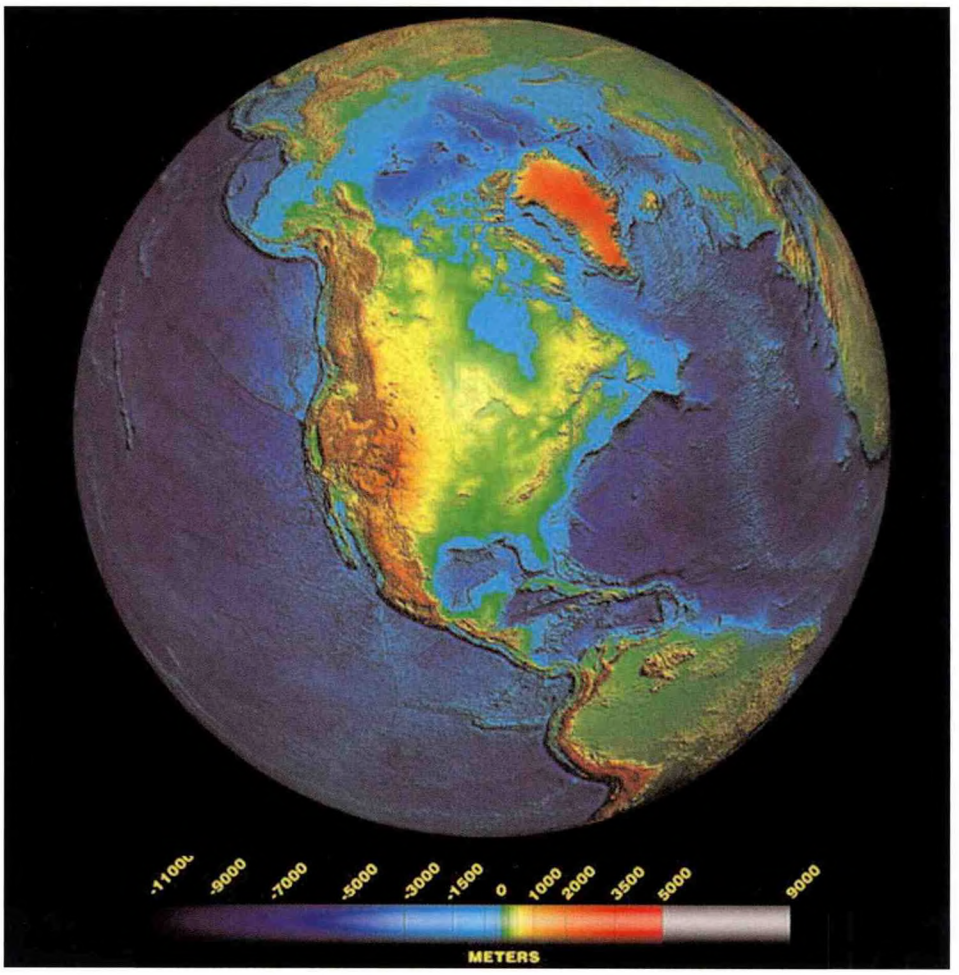


Figure 3-DOC-11. Relief Global Slide sets available from NGDC.

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 both ground-based and satellite instruments, are managed by the National Snow and Ice Data 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, timelier 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*).

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*)

National Snow and Ice Data Center

The National Snow and Ice Data 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

Global Historical Climatology Network

The Global Historical Climatology Network (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 (*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 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 *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 *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. Instruments 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 *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 *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. Improving flood forecasts fall under the component of USWRP labeled "Improving Quantitative Precipitation Forecasting." 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.

A significant focus of OAR in the weather and air quality area is the development of operational test beds under the auspices of the USWRP. These test beds are the mechanism through which research is transitioned to operations. It is recognized by the USWRP that, since NOAA is one of the forecast mission agencies in the program and the program goals are predominantly operational ones, its most significant role in the USWRP is to provide the infrastructure and capabilities to efficiently and effectively test research products in an operational environment. The test beds being developed are the Joint Center for Satellite Data Assimilation (JCSDA), the Joint Hurricane Test-bed, and the Mesoscale Numerical Weather Prediction Test Bed. These test beds are operated in partnership with other USWRP agencies. OAR's role is to provide the directed research and operational testing, in partnership with the National Weather Service (NWS). In addition, the development of the Weather Research and Forecasting (WRF) modeling architecture, also under the auspices of the USWRP, will provide a common modeling structure to be shared by most of the test beds and between the research and operations communities. Several OAR laboratories are involved in the WRF development in partnership with the NWS and other USWRP agencies.

Observing Technology

Two OAR laboratories in Boulder, Colorado, and one in Norman, Oklahoma, are heavily involved with developing new environmental observing system technologies. The new activity for FY 2002 will be the planning and very early establishment, under the direction of the USWRP, of observational test-beds which will provide an environment to evaluate new observing systems and suites of observing systems in order to decide on their efficacy for operational use. It also provides observations for testing data assimilation methodology, much of which will be under the direction of the North American Atmospheric Observing System (NAOS) Council made up of the United States, Canada, Mexico, Central America, and the Carribean. Data assimilation is the link between observations and modeling.

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 (Figure 3-DOC-12) .

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 super-pressure 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 and with launches near the Oregon coast. 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 a related balloon development effort, the Idaho Falls Division of the Air Resources Laboratory is refining its constant-level "smart" balloon, intended to serve as a marker of parcels of air moving across the countryside and permitting samples to be made of the changes occurring in its composition. The Idaho Falls group is also active in the development of high wind speed sensors, such as are used on aircraft and for studies of hurricanes. A specialized probe to measure turbulence during hurricanes is now nearing completion, as a joint project with the Oak Ridge Division of ARL. The Oak Ridge group continues to lead in the development of specialized sensors for measuring atmospheric turbulence. Their systems are now widely used for measuring the efficiency of coupling between the air and the surface, and have recently been selected for instrumenting the latest generation of research aircraft, manufactured in Italy.

During FY 2002, ETL and FSL will continue development of new sensors and innovative techniques for combining observing systems synergistically

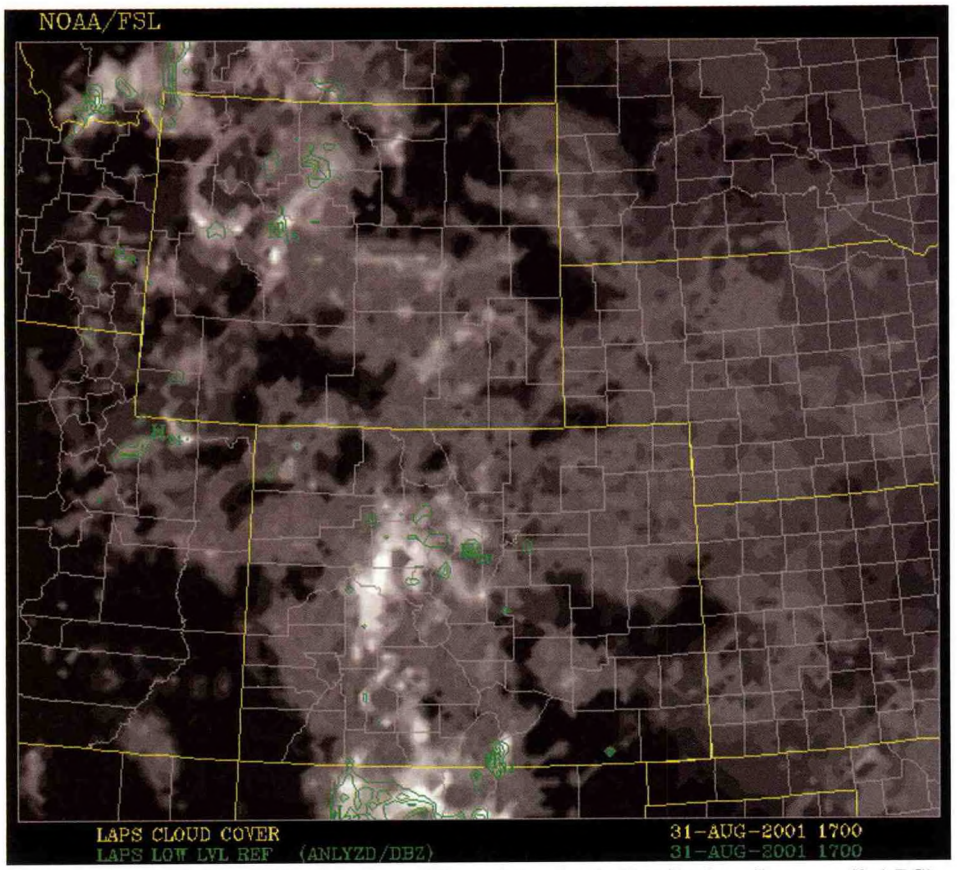


Figure 3-DOC-12. FSL-developed Local Analysis Prediction System (LAPS) can generate model predictions of cloud cover.

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.

ETL scientists, in conjunction with NASA, are also investigating the potential of a new observational platform featuring Unmanned Aerial Vehicles or UAVs. The concept is to deploy specialized cameras called hyperspectral imagers on these remote-controlled, solar-powered aircraft. Recent developments indicate that UAV's will eventually be capable of flying indefinitely at altitudes exceeding 50,000 ft, higher than most weather events, but much lower than satellites, making them ideal observational platforms. Dubbed Peacewing, ETL scientists envision many potential applications of this technology. Images from UAV-mounted cameras can be used to enhance satellite images of severe storms such as hurricanes. This platform can also be used to monitor the health of coral reefs. It can also be flown over land to assess moisture content of soil and vegetation, both of which are indicators of drought and fire susceptibility. Peacewing is a perfect complement to satellite-borne sensors and ground based systems.

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.

Icing is a weather hazard that occasionally causes aviation disasters, especially in winter. In-flight icing forms on wings and other exposed surfaces as an aircraft flies through clouds that contain super-cooled liquid water droplets. Leveraging earlier work with polarization-sensitive cloud radars, ETL is designing a new ground-based cloud radar and radiometer system to monitor clouds in the vicinity of airports and to provide automated warnings of icing conditions aloft. This instrument is the Ground-based Remote Icing Detection System (GRIDS). It will form the initial component of the FAA Icing Remote Sensor Testbed (FIRST). Development of the pilot demonstration unit is sponsored by the FAA as part of a proposed new NWS initiative.

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 is known for its role in the development of the WSR-88D NEXRAD radar. Regarding the radar software, NSSL is presently working to improve the WSR-88D software algorithms used by the NWS forecasters. Regarding the radar hardware, NSSL is exploring ways to enhance the WSR-88D hardware using dual polarization techniques. Most weather radars, including the WSR-88D NEXRAD radar, transmit radio wave pulses that have a horizontal orientation. Polarimetric radars (also referred to as dual-polarization radars), however, transmit radio wave pulses that have both horizontal and vertical orientations. The horizontal pulses essentially give a measure of the horizontal dimension of cloud (cloud water and cloud ice) and precipitation (snow, ice pellets, hail, rain) particles while the

vertical pulses essentially give a measure of the vertical dimension. Since the power returned to the radar is a complicated function of each particle size, shape, and ice density, this additional information results in improved estimates of rain and snow rates, better detection of large hail location in summer storms, and improved identification of rain/snow transition regions in winter storms. The first step in the processing is to prototype a new Radar Data Acquisition (RDA) unit 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 provide ground validation research in support of the NASA Tropical Rainfall Measuring Mission (TRMM). Profiler observations were made by the Aeronomy Laboratory during several TRMM Ground Validation Field Campaigns in 1998 and 1999. These observations have provided important information on the vertical structure and temporal evolution of precipitating cloud systems during these campaigns. The profiler observations have been made available to the TRMM Science Team and can be viewed on the Aeronomy Laboratory web page. The observations made during the field campaigns are the subject of collaborative research with other TRMM researchers 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. One profiler is being maintained for TRMM on Legan in Kwajalein to obtain a longer term perspective on the structure of precipitating clouds and the variability of drop size distributions in oceanic precipitation. Validation of drop-size distributions used in algorithms is key to improving the retrieval of rainfall estimates from the TRMM satellite. In 2001 the Aeronomy Laboratory will participate in the EPIC 2001 field campaign in the eastern Pacific by operating a profiler for precipitation studies on the R/V New Horizon. The EPIC campaign is part of the PACS program and is designed to improve understanding of the eastern Pacific ITCZ cold tongue complex.

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 2002, NSSL will continue to develop techniques in cooperation with the NWS to forecast and warn of weather hazards to aviation and the general public. Knowledge gained from the VORTEX experiments in the mid and late 1990's, and subsequent experiments like

MeaPRS, provide new understanding of severe thunderstorms, storm electrification, and tornadoes and lead to improved methods to detect, model, and predict these storms. Also in FY 2002, NSSL will conduct an experiment called TIMEx, Thunderstorm Initiation Mobile Experiment. TIMEx is a series of field programs and analyses designed to answer specific questions concerning the evolution of convective precipitating systems. Immediate technology transfer will be effected by close association with several NWS Weather Forecast Offices, including Norman and Tulsa, Oklahoma; Phoenix, Arizona; Melbourne, Florida; Jackson, Mississippi; Fort Worth, Texas; Denver, Colorado; and Salt Lake City, Utah.

NSSL works closely with the NWS WSR-88D Radar Operations Center (ROC). Together, they are re-hosting the Radar Product Generator, the Radar Data Acquisition system, and the Principal User Processor to an open systems computation platform. The re-hosting will continue for the next several years and will result in vastly improved capabilities for the WSR-88D radar. The new system will ease the incorporation of new software applications and allow for integration of new hardware technology into the radar system resulting in less time needed for technology transfer. ORPG deployment for 170 total radar sites, both operational and non-operational, will begin August 2001 and run through FY 2002.

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-the-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 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-13).

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. Recent

Figure 3-DOC-13. CALJET sensor package

experiments called MeaPRS (MCS Electrification and Polarimetric Radar Study) and STEPS (Severe Thunderstorm Electrification and Precipitation Study) were conducted to improve the science behind the technology. MeaPRS was specifically designed to investigate Mesoscale Convective Systems (MCS) electrification processes and ways to improve understanding of polarimetric radar measurements in preparation for possibly upgrading NWS radars in the future. STEPS was designed to improve our understanding of how severe storms become electrified and to better understand how variations in type and flash rate of lightning relate to the type of severe storm and its evolution. Other studies underway are focused on the precipitation structure of mesoscale convective systems, the interactions between mesosconvective 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 2002, NSSL will continue to investigate various model convective parameterization schemes, along with our techniques to improve model initialization through four-dimensional data assimilation.

NSSL is working with the NWS Storm Prediction Center (SPC) to improve their ability to forecast severe weather and to provide severe winter weather guidance products. Data collected during the Intermountain Precipitation Experiment (IPEX) held in FY 2001 should help. The data are being analyzed by NSSL, the NWS Storm Prediction Center, and University of Utah scientists. The IPEX field and research program was designed to improve the understanding, analysis, and prediction of precipitation and precipitation processes in complex terrain. Data analysis of IPEX will continue in FY 2002.

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. To this end, ARL maintains the nation's surface radiation network (SURFRAD), data from which are now routinely employed to test both forecast mesoscale models (such as Eta) and satellite outputs. 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.

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. The 1998 campaign will be repeated 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. Through 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.

Under the USWRP, OAR, NWS, NESDIS, and the USWRP participating agencies are currently establishing a Joint Hurricane Test-bed (JHT) at the Tropical Prediction Center in Miami. It is anticipated that the JHT will grow in FY 2002 as more resources become available. This test-bed is where the hurricane research will be evaluated for operational use and those research products passing the test will be handed off to operations.

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. GFDL is in the process of establishing a unit, the Technology Infusion Group, at the National Centers for Environmental Prediction (NCEP)/NWS, to facilitate the transition into operations of advances in coupled climate forecast systems and the ocean data assimilation systems required to initialize these forecasts.

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, terrestrial, 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 air-

craft 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 preparedness 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.

Air quality forecasting is a major theme of ARL research. Over the last several years, ARL has made ozone forecasts available to interested researchers, via the web, with focus mainly on the area surrounding the Great Smoky Mountains. In this area, ozone exceedances are reported with increasing frequency, and forecasts of ozone levels are being requested by federal and state agencies alike. The ARL effort in this regard is targeted through its East Tennessee Ozone Study (ETOS), which has been a focus for regional air quality attention for the last three years. In future years, it is planned to develop air quality forecast capabilities using the supercomputing center of the University of Nevada at Las Vegas, through the formal linkage with the Cooperative Institute for Atmospheric Studies and Terrestrial Applications (CIASTA).

ARL operates two national networks that direct research attention 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 2000, a comprehensive air quality field experiment took place in the region around Houston Texas. This experiment was designed 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 anthropogenic 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-timescale 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. Research efforts will also focus on an evaluation and improvement of the tools used to forecast future air quality and the observing systems needed to evaluate their skill. 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.

In the summer of FY 2001, an evaluative testing will begin using a regional ozone forecasting model. The model will be run at the Skaggs Center in Boulder, Colorado. Candidate regions include Texas, North Carolina, and New England, all which have significant ozone problems. This test will mark the beginning of the establishment of a regional air quality forecasting test-bed which may expand to other atmospheric constituents.

Space Environment Services and the Space Environment Center

NOAA and the Air Force jointly operate the National Space Weather Operations (SWO) group in NOAA's Space Environment Center (SEC) in Boulder, Colorado. The SEC, working closely with the Air Force Weather Agency (AFWA), provides forecasts, alerts, indices, and summaries of disturbances occurring on the Sun, in space, in the geomagnetic environment, and in the upper atmosphere (Figure 3-DOC-14). 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 protect astronauts from harmful radiation.
- 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. The United States Air Force operates a space weather operations center at Air Force Weather Agency (AFWA) to provide space weather support, including products from the SWO, to DOD assets. The AFWA 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 AFWA space weather operations group shares space weather data and support responsibilities with its civilian counterpart at SEC.

SEC serves as the international World Warning Agency for the International Space Environment Service (ISES). It exchanges international data--solar-wind, X-ray,

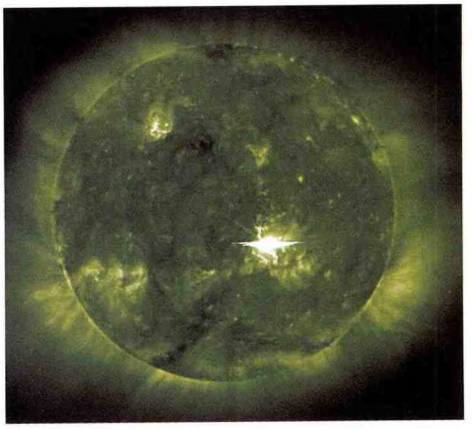


Figure 3-DOC-14. A solar flare (a sudden, rapid, and intense variation in brightness) occurs when magnetic energy that has built up in the solar atmosphere is suddenly released, launching material outward at millions of kilometers per hour. Observed by Solar Heliospheric Observatory (SOHO) on May 2, 1998.

sunspot, corona, magnetic, and ionospheric measurements--in real-time and, from these data, provides 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.

Research and development at the Space Environment Center emphasizes understanding of the fundamental physical processes governing the regime from the solar surface, through the interplanetary medium, into the magnetospheric-ionospheric regions, and ending in Earth's upper atmosphere. These processes are manifest in the climatology and disturbances of Earth's magnetic field, the ionosphere, the charged particle populations at satellite orbits, and the atmospheric density at high altitudes (including low-Earth orbit). Our research is focused on areas where advanced applications can be developed and prototyped to improve space weather services, whereby the nation is served through alerts and warnings of those conditions that can be often hazardous to technological systems in space and on the ground and human activities in space.

Solar Terrestrial Models and Theory. SEC work is also devoted to basic research of Earth's space environment and the application of this research to space weather operations. The staff has expertise spanning from solar physics to Earth's upper atmosphere, and maintains close collaborations throughout the research community. They publish regularly in scientific journals, and work directly with the SEC Space Weather Operations and the Systems Division to develop state-of-the-art capabilities for the NOAA/SEC forecast center.

Solar Terrestrial Instrumentation and Data. The group ensures that space environment data are processed, validated, interpreted, and disseminated in an efficient and timely fashion. The group develops analysis tools for working with data from a variety of spacecraft, including the NOAA geosynchronous and polar orbiters, and spacecraft in the solar wind. Data access is provided through customized data-analysis routines and individualized displays. In addition to enhancing the utility and value of the primary data through research and analysis, the group explores sources of new data and improved monitoring to support Space Weather Operations.

Solar Influences and Imaging. SEC conducts research into understanding processes on the sun and the effects of solar activity on the near-Earth space environment. The group leads in the development of techniques to process and interpret both ground-based and space-based solar imagery, and has special expertise in solar X-ray imaging. To support Space Weather Operations, the staff examines both short and long-term solar influences on human activities in space and on the ground.

Rapid Prototyping Center. A unique facility dedicated to moving space environment models from a research-development mode to an operational mode.

Satellites. Developing space monitoring instrument specifications, receiving and validating data from these instruments, analyzing and presenting data, and archiving data in the National Geophysical Data Center (NGDC) are all aspects with which the SEC is involved. The Space Environment Monitor (SEM) instruments on the Geostationary Operational Environmental Satellite (GOES) and the Polar-orbiting Operational Environment Satellite (POES) are among our major responsibilities. The SEM instruments on POES include energetic particle monitors and SBUV. The SEM instruments on GOES include magnetometers, energetic particle monitors, and solar x-ray intensity measurements. Future GOES will add measurements of the extreme ultraviolet (EUV), a Solar X-ray Imager, and a broader range of energies of energetic particles. In addition, we cooperate with other agency satellite missions to provide real-time space weather information. These include the NASA missions: WIND, ACE, and IMAGE. In FY 2002, SEC will emphasize improvement of space weather observations.

Solar X-Ray Imager. A Solar X-ray Imager (SXI) telescope will be flown on the GOES M satellite, due for launch late in FY 2001. The SXI will provide images of the solar atmosphere on time scales of an image every few minutes. The SXI telescope based on recent research instruments flown on American and Japanese satellites will enable observations of the three-dimensional structure of solar disturbances as they develop and propagate in the solar atmosphere. The new instrument will fill an important gap in the ability to model and predict space weather disturbances as they propagate

from the Sun to Earth. First level integration of the SXI data into space weather operations will be completed early in FY 2002 and successive incremental implementations will be made later in the year.

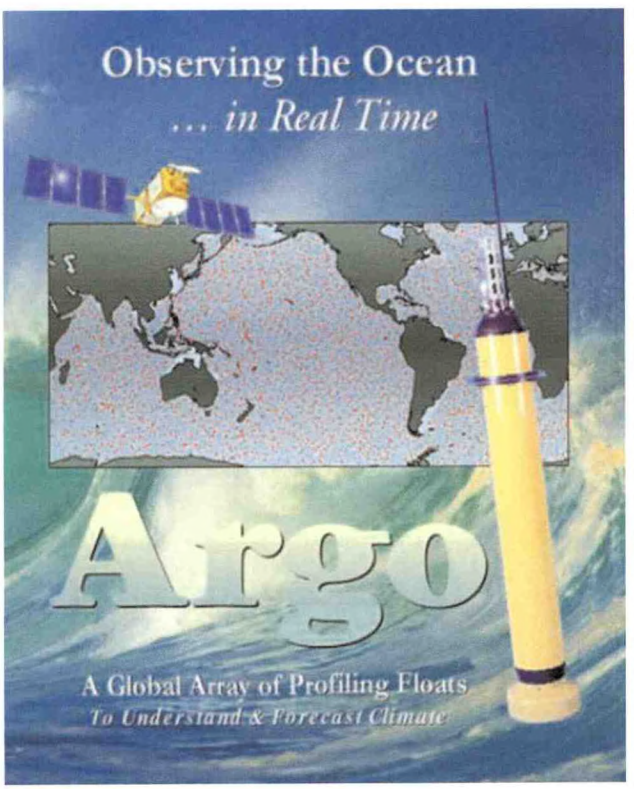
GOES NO/PQ satellites. SEC will be completing full implementation of the ingest, processing, analysis, and distribution of the new instruments that allow measurements of the environment immediately surrounding the satellite. The measurements, of low energy but dense radiation, will improve our capability to specify conditions that can interrupt or disable satellite operations. The use of models being developed in the research community and evaluated for operational use in SEC will allow the new measurements to be extrapolated throughout near-earth space. With the combination of new measurements and models, the environment can be specified at any location for the hundreds of satellites in geosynchronous orbit around Earth.

Expanded use of the NOAA Space Weather Scales and New Products. Use of the NOAA scales for classifying space weather disturbances continued to increase through FY 2001. Several new alert categories have been developed and implemented to make use of the scale in response to users who find the scales offer more useable information than previous, often overly technical alerts.

SEC will propose additional space weather products, including new alerts and graphical products, for assignment of World Meteorological Organization (WMO) codes to facilitate the SEC program to integrate space weather products into the NOAA suite of weather services. This continues a series of implementations of space weather products into the NOAA Family of Services.

New products describing the location and intensity of the energy put into the atmosphere by the aurora are being put in place in FY 2001 and this effort will continue in FY 2002, using data from the POES.

SEC will participate directly in interagency programs directed at improving our understanding of the space environment. These include the Living With a Star Program (a NASA initiative), and three cooperative campaigns covering the Sun, Earth's magnetic field, and the ionosphere.



Use of Global Positioning System (GPS) to measure the ionosphere. SEC, in cooperation with FSL and with support from the DOD, will continue to develop a capability to measure the ionosphere, including its electron content and height, through use of the DOD Global Positioning System (GPS). By recording thousands of GPS signals each day and using data assimilation techniques that allow the measurements to be reversed, the ionosphere can be mapped in greater detail than with current measurement systems.

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.

Figure 3-DOC-15. NOAA Research Vessel Ronald H. Brown.

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 (Figure 3-DOC-15). The system has been shown to not only be effective for studying convective processes but also processes associated with marine stratus clouds. In August-October of 2000, NOAA/ETL installed and tested a novel phased array, electronically stabilized radar for measuring wind profiles above the ocean. This profiler will be used to monitor winds in several upcoming field experiments (e.g., EPIC 2001, PACS 2001).

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 to provide 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.

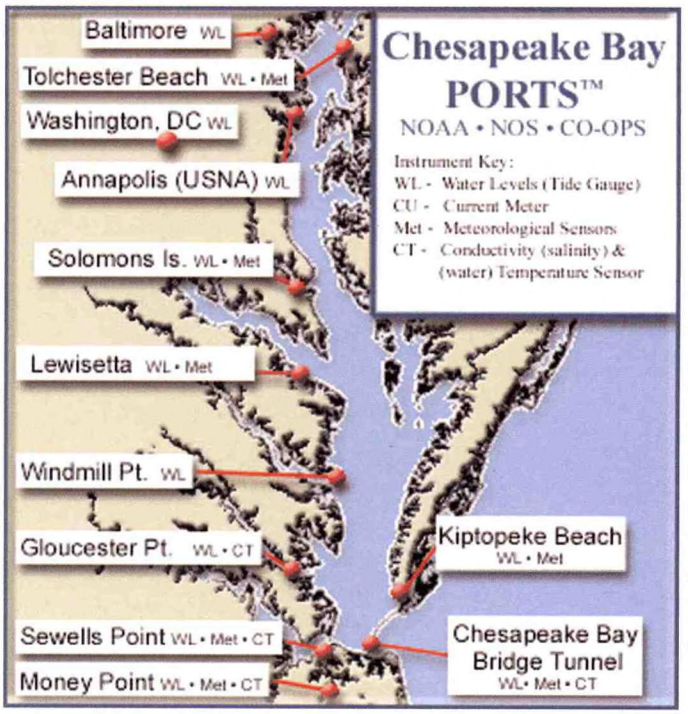


Figure 3-DOC-16. PORTS sites in the Chesapeake Bay.

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) was designed to operate on a 24hour/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. An advanced version of this system, CORMS II, is presently in developmental stages (Figure 3-DOC-16).

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. Bridge mounted "Air Gap" sensors for water level detection are presently being developed and are included in future plans for PORTS™.

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. (Figure 3-DOC-17).

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 coastal marine ecosystems. PORTS™ provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides

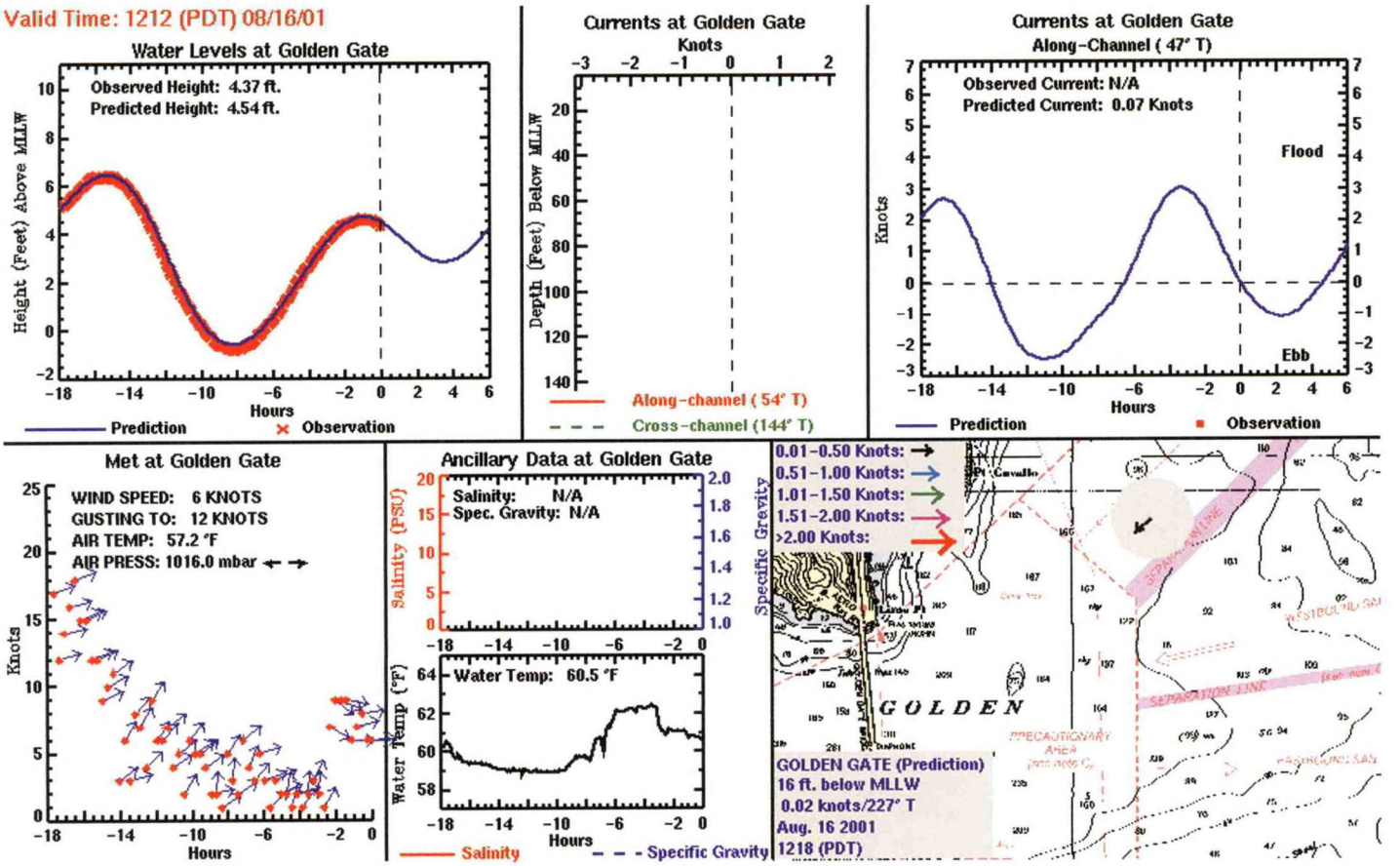


Figure 3-DOC-17. San Francisco Bay PORTS: Golden Gate Composite.

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. 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.

OFFICE OF NOAA CORPS OPERATIONS
AIRCRAFT OPERATIONS CENTER

The Aircraft Operations Center (AOC) provides aircraft support to many NOAA missions, several of them associated with the Natural Disaster Reduction 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 hydrologic data for soil moisture forecasts, aerial photography and remote sensing 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 data recording systems, and processes and analyzes data sets collected during various field programs.

AOC has integrated into its operations a 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 GPS dropwindsondes and transmits the resulting profiles of thermodynamic and wind information to the NCEP and the National Hurricane Center (NHC) for inclusion into 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 is also beginning to 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 the Air Force Reserve aircraft reconnaissance during particularly active storm periods when tasking requirements exceed available resources.

Land-falling hurricanes, a major subject of the United States Weather Research Program and NDRI, receive particular attention from AOC aircraft. During the 1998 hurricane season, the G-IV and 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 the Air Force Reserve and National Aeronautics and Space Administration aircraft, the 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. This experiment will be repeated in 2001 as CAMEX-4.

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 is a Total Force organization, employing the active forces as well as Air Force Reserve and Air National Guard weather personnel. The active component of AFW has nearly completed reengineering 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 fulfilling 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 split between HQ AFWA and the 55th Space Weather Squadron (55 SWXS) at Schriever AFB, Colorado, as the transition of strategic-level space weather functions to AFWA continues. Eight 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) in concert with their supported NAFs or Theater's AOR (Figure 3-DOD-1). Continental United States (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 at the base and post level, take and disseminate local observations and provide mission-tailored forecasts and briefings based on centrally produced guidance. In addition to the active duty force, approximately 110 weather officers serve as Air Force Reserve individual mobilization augmentees assigned to various active AFW units at all levels. They typically train during two days each month and for two weeks each year. The Air National Guard (ANG) program consists of two distinct functions. 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. The ANG operates the Weather Readiness Training Center 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 support. Total Force AFW per-

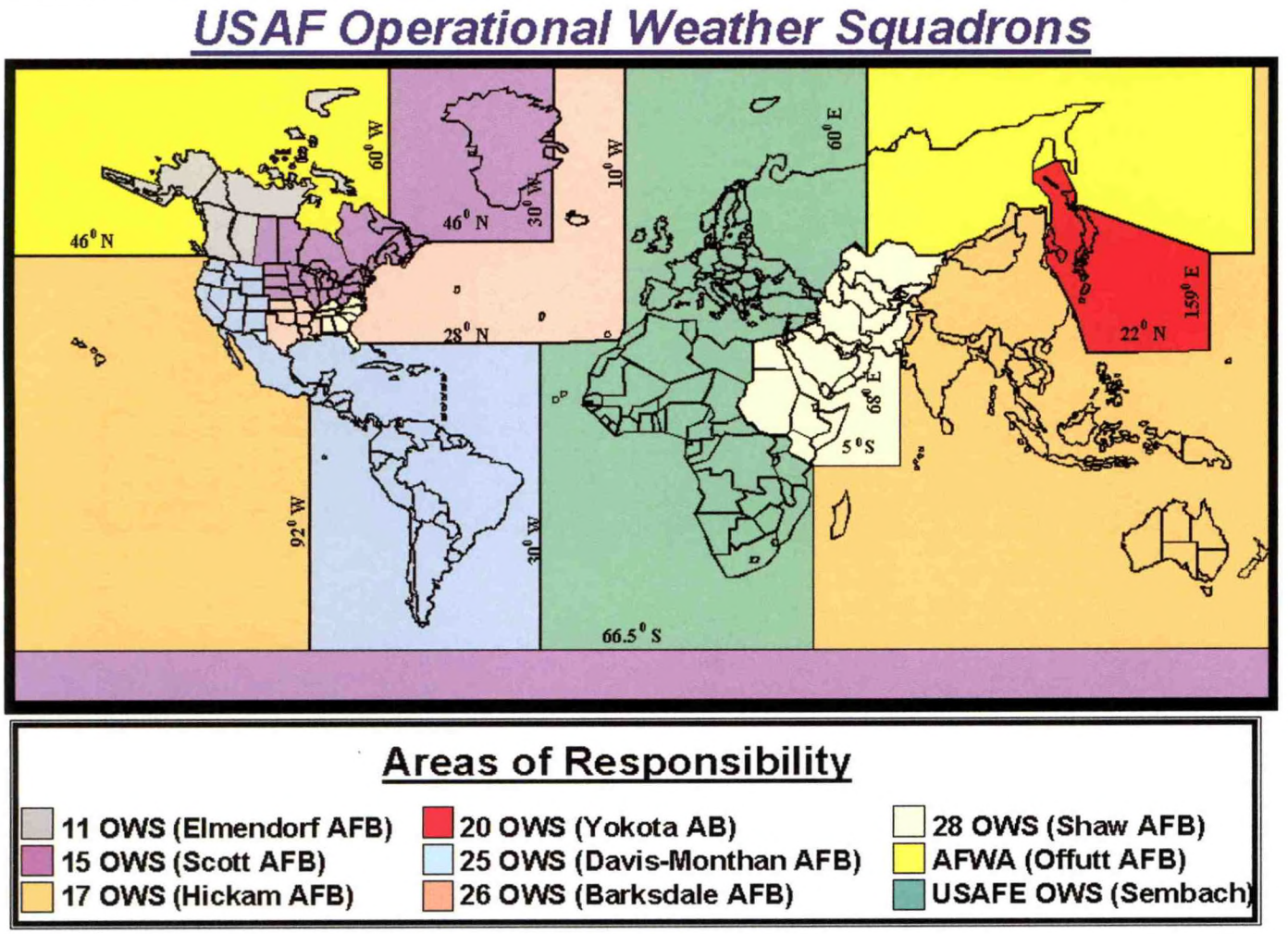


Figure 3-DOD-1. Areas of Responsibility for Air Force Weather's Operational Weather Squadrons.

sonnel 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.

To fulfill its global mission of providing timely, accurate, and relevant weather information, AFW maintains and continually improves on its five core processes: data collection, analysis, forecasting, tailoring, and dissemination. The following paragraphs provide more information on each of these areas.

Weather Data Collection integrates the spectrum of remote and *in situ* sensors into a single meteorological sensing and instrumentation approach for battlefield and in-garrison operations. Data collection in the space environment is discussed in the Space Environmental Services section.

AFW personnel take surface observations to support military operations and for weather analysis and forecasting. Weather personnel at both Air Force and Army locations (fixed and tactical) make observations available to local users and transmit them to military and civil locations throughout the world via the Automated Weather Network (AWN). Upper air observations provide vital input to numerical weather analysis and prediction. United States and foreign rawinsonde reports are primary sources and are supplemented with military and civilian pilot reports. The Observing System 21st Century (OS-21) program provides 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 configuration is intended for tactical operations and continues the improvements begun under the Manual Observing System (MOS) and Tactical Meteorological Observing System Modification (TACMET MOD) programs. For remote observations, AFW purchased commercial off-the-shelf Remote Miniature Weather Sensors to provide accurate real-time weather information from forward unmanned locations. Installation of the new fixed configuration should begin in FY 2002.

Weather radar is a principal source of information needed to produce severe weather warnings. Within the CONUS, AFW uses the WSR-88D. DOD, NOAA, and the FAA operate

and maintain the radars within CONUS and the Air Force operates and maintains the overseas radars. Tactical Weather Radars (TWRs) are used to support worldwide military contingency operations by providing tactical/deployable weather radar capability, replacing existing radars at deployed locations and at select fixed locations overseas.

The Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, is a vital 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, electrically charged particle fluxes, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional imagery and mission-sensor data to DOD land-based and shipborne terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses the Operational Linescan System to provide visible imagery to optimize distinction among clouds, ground, snow, and water. The DMSP also flies a microwave temperature and moisture sounder (SSM/T, SSM/T-2) which provides vertical temperature, moisture, and height profiles of the atmosphere, providing key data 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 Block 5D-3 spacecraft will begin service in November 2001 with the launch of DMSP Flight 16. The new spacecraft will provide enhanced microwave imaging and sounding through the SSMIS system as well as several other improvements.

AFW continues to participate in the refinement of requirements for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS will replace the existing DMSP and NOAA polar-orbiting satellite systems beginning in approximately 2010 and is a joint Department of Defense, Department of Commerce, and NASA program. The new system will also provide a direct readout capability for tactical users similar to DMSP. AFW also expects to gain operational experience as well as benefit from the risk reduction planned with the NPOESS Preparatory Program (NPP) planned for launch in CY 2005.

To receive environmental current satellite downlinks, the Small Tactical Terminal (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 remotely-sensed visual and thermal imagery and other non-imagery weather data from both polar-orbiting and geostationary satellites to support combat forces.

The Air Force Reserve Command's 53rd Weather Reconnaissance Squadron (53 WRS) "Hurricane Hunters" provide another means of collecting vital meteorological data, especially in and around tropical cyclones. Their specially-equipped WC-130 aircraft collect temperature, moisture, wind, pressure, and visually-observed information at the aircraft location as well as vertical profiles of the atmosphere collected by dropwinsondes. They penetrate the eyes of tropical cyclones to provide a very accurate center fix location as well as providing meteorological parameters, including sea level pressure, to the National Hurricane Center. In addition to the tropical cyclone reconnaissance mission, the 53 WRS collects meteorological information to improve wintertime West Coast forecasts as well as supporting scientific field programs when possible. For more information, see their web site at *http://www.hurricanehunters.com/*.

Analysis and Forecasting. AFWA is the primary strategic production center for weather analyses and forecasts while the OWSs are the primary theater-scale production centers 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. World-wide 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 manipulation of satellite and conventional meteorological data to prepare forecasts and other environmental products. AFWA also

provides backup for the National Weather Service's (NWS) Storm Prediction Center and Aviation Weather Center.

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, and national customers; produces long-range (4-8 day) forecasts to unified command, component, and 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. As the space weather mission transitions from 55 SWXS to HQ AFWA, SSOB provides worldwide general and tailored analyses, forecasts, advisories, and warnings for space weather phenomena that can affect military operations and National Programs activities. The branch provides 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.

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 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 unclassified and classified web-based 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; backs up the Washington Volcanic Ash Advisory Center; 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 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.

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 System (SWAFS), and modernization of the communications and data processing infrastructure including a significant increase in the database capacity. CDFS II brings 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 nearly complete and will improved interaction of the strategic and OWS theater-level forecasting systems. 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.

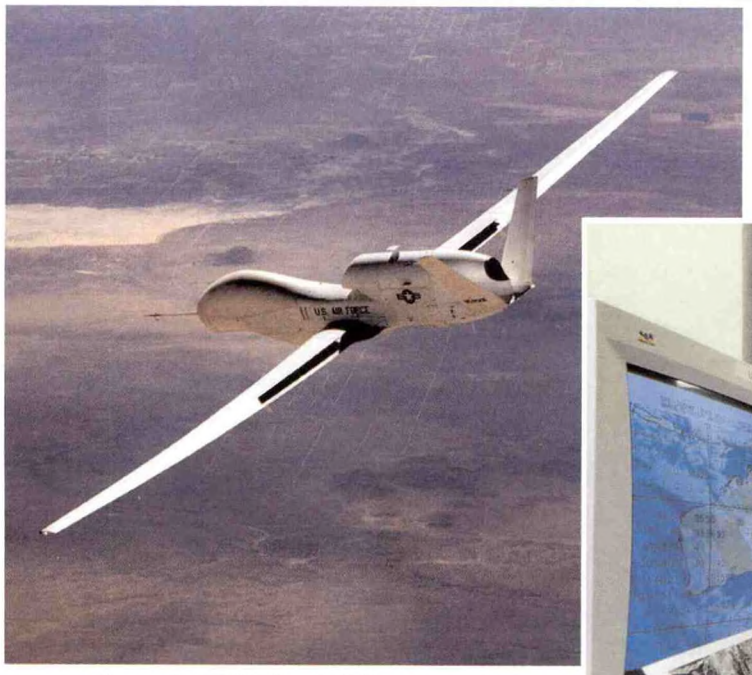


Figure 3-DOD-2. AFW personnel from Wright-Patterson Air Force Base, Ohio, scan up-to-the-minute weather charts and satellite reports to provide United States and Australian command and control operators critical flight safety information for Global Hawk.

OWSs provide theater-scale battlespace forecasts; drop zone, range, and aerial refueling track forecasts; fine-scale target forecasts; and airfield forecasts and warnings for Air Force and Army installations within their area of responsibility. Their primary tool is the OWS Production System II (OPS-II), used to ingest data and strategic center information, create and disseminate theater-scale products.

Product Tailoring/Warfighter Applications. Progressive focusing and tailoring of weather information is the heart of the reengineered AFW organization, leading to individual mission-specific support at the CWT level. An example of specific mission tailoring performed for an emerging system still in testing is the Global Hawk high-altitude reconnaissance system and the turbulence forecasts provided by the weather support team (Figure 3-DOD-2). 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. This hybrid system of databases, servers, and workstations, 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.

Dissemination. The AFW dissemination system uses a variety of media to meet the needs of its worldwide customer base. High-speed communications between large DOD and civilian processing centers facilitate sharing of data, high-resolution satellite imagery, and output from numerical weather prediction models. Additional circuits provide a subset of this data to the OWS 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 worldwide using dedicated 9600-baud circuits. AFW will continue replacing these dedicated circuits in FY 2002 with commercial Kμ-band broadcast satellites over the CONUS, Europe, and the Pacific, saving significant communications costs by eliminating the network of expensive landlines to each weather station.

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 Nonsecure Internet Protocol Router Network (NIPRNET), and (3) HF and satellite broadcast facilities. The current HF Regional Broadcast (HFRB) system will be terminated in FY 2002 and replaced by more reliable satellite-based, worldwide-capable communications.

AFW utilizes the NIPRNET to host the Joint Air Force-Army Weather Information Network (JAAWIN) and the Military Aircrew Information System (MAIS). JAAWIN provides worldwide access to numerical model forecast graphics, satellite imagery, and text bulletins. MAIS uses aircrew mission parameters and provides weather data for the takeoff base, route of flight, and destination. MAIS will be replaced in FY 2002.

Additional means of dissemination of tailored weather information include the Joint Weather Impacts System (JWIS). JWIS provides a link to weather information from both AF and Navy sources for use by command and control users and applications. AFW successfully demonstrated JWIS during Joint Expeditionary Force Experiment 2000 and is integrating the initial capability into the Combined Air Operations Center-Experimental (CAOC-X) in 2001. AFW is also seeking rapid acquisition process funding in FY 2002 for the Weather Impacts Information Integration (WI^3) initiative to provide a four-dimensional weather data cube to feed decision aids integrated in command and control systems.

Finally, AFWA established in 2001 an initial capability to provide weather information to any AF user through the new Air Force Portal, a system designed to be a "one-stop shop" for all support-type activities for all AF personnel. Additional capabilities will be added in 2002.

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 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 tailored forecasting 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 (3-D) 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.

The Air Force Director of Weather 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 with 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.

SPACE ENVIRONMENTAL SERVICES

The 55 SWXS has been the DOD focal point for space environmental support and the transition to AFWA of the strategic functions of the 55th will be completed during FY 2002. The 55 SWXS currently oversees six solar observatories located throughout the world and participates with NOAA in the operation of NOAA's Space Environment Center.

Many DOD systems are affected by space weather phenomena that occur in the near-Earth environment. Space weather impacts fall in three general categories: electromagnetic radiation, high-energy charged particles, and electrically charged particle clouds. Figure 3-DOD-3 includes information on the arrival times, duration, and effects of these events. AFWA provides a suite of automated and manually tailored space weather products to the range of customers susceptible to these impacts.

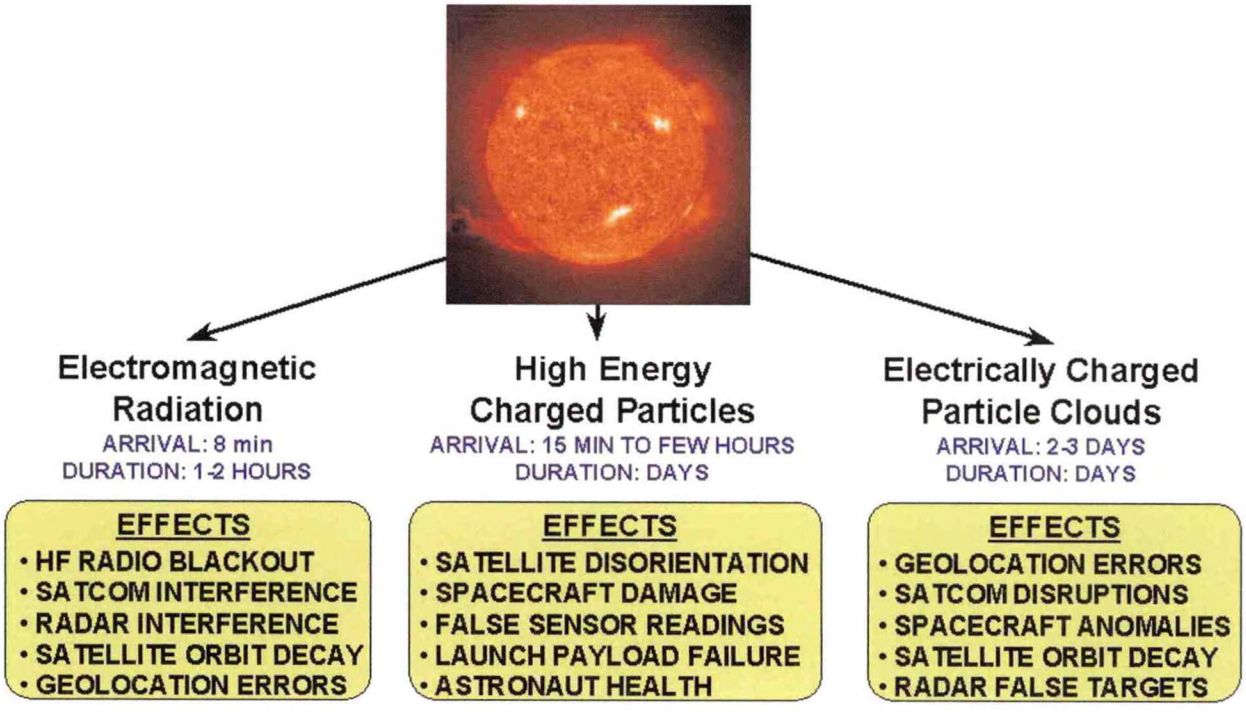


Figure 3-DOD-3. Solar activity produces radiation and particle effects in the near-Earth environment which affect military operations.

Sources of Space Environmental Information. 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 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 measurements of disturbances in the ionosphere. The Jet Propulsion Laboratory also operates a complementary global network of sensors providing ionospheric data and the United States Geological Survey (USGS) operates a network of magnetometers. The USGS data provides indirect measurements of the strength of ionospheric and magnetospheric electric currents which create their own magnetic field superimposed upon the Earth's magnetic field.

The Geostationary Operational Environmental Satellite (GOES) vehicles provide real-time solar X-ray, electrically charged energetic particle, and geomagnetic data, 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. Additionally, AFW leverages space-based data from NASA and other agencies. For example, NASA's Advanced Composition Explorer satellite provides real-time solar wind data.

A number of additional sensors or improvements to existing space weather sensors are planned. The Solar X-Ray Imager (SXI) recently went into orbit aboard GOES-12. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. AFW expects the first Solar Radio Burst Locator (SRBL) to become operational in 2002 to provide radio wave measurements of the Sun while also mapping certain solar phenomena blocked from optical view by cloud cover. AFWA has additional improvements scheduled for the optical telescopes as well as for the ionospheric sensors.

AFWA uses a suite of space weather models to specify current solar or global characteristics of space weather where observations are not available and to assist in forecasting future conditions. These models use available observations and and include both climatology-based and physics-based algorithms.

More detailed descriptions of both the available observations and current models are available in Chapter 2 of the *National Space Weather Program Implementation Plan*, Second Edition, available from OFCM.

Mainstreaming Space. AFW initiated an effort in FY 2001 to mainstream space weather for both the providers and users and will continue this effort in FY 2002. DOD's increasing reliance on space weather-affected systems, continuing expansion of operations into space, and the Air Force's designation as executive agent for space indicates space weather support will become increasingly important. AFW will treat space weather initiatives the same as terrestrial weather initiatives and the spectrum of weather information users should think of space weather as quickly as they do terrestrial weather. The AFW goal is to create a seamless, real-time depiction of the entire natural environment from the mud to the Sun. The realignment of the 55 SWXS is part of this effort as well as the planning, programming, and budgeting for space weather initiatives following the National Space Weather Program and National Security Space Architect space weather architecture. AFW is taking steps to standardize support, improve space weather training for both providers and users, integrate dissemination channels for both space and terrestrial weather, and improve customer interaction. To improve interaction, AFW in conjunction with the AF Flight Standards Agency (AFFSA) is modifying the flight weather briefing form to include space weather effects on navigation and communication and establishing a space weather "pilot report" process to obtain feedback to identify, quantify, and archive space weather impacts.

SUPPORTING RESEARCH

The overarching objective of the Air Force meteorological and space environmental R&D program is to provide system designers, operational weather support personnel, and weather information users with the technology and 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. 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 *Transition Plan* as well as the *National Space Weather Program Implement-ation Plan, Second Edition*.

In meteorological R&D, the AF is improving numerical weather prediction, studying such problems as optical turbulence, and has transitioned key advances in tactical decision aids into operations, permitting improved forecasting of electro-optical system performance and generation of cloud and target scene visualizations for training, system development, and mission rehearsal. More detailed information on weather impact decision aids was

provided in this section of last year's Federal Plan. In addition to internal efforts, AFW will continue to rely on collaboration and leveraging of efforts with other federal meteorological agencies, research labs, and universities to meet supporting research needs.

Mesoscale Modeling for Air Force and Army Operations. Supporting research in the area of mesoscale numerical weather prediction continues to pay dividends. Recent research paid off in 2001 with the AFWA MM5 implementation of the Land Surface Model (LSM) to support Air Force and Army operations worldwide. The LSM analyzes the current state of the land surface to provide information to both DOD and civilian agencies and, through coupling with MM5, improves forecasting performance in the low levels. This allowed AFW to improve forecasting for low-level aircraft operations, trafficability for ground forces, dispersion of contaminants, and employment of precision guided munitions. The advances achieved in the LSM are also being carried over into Weather Research and Forecasting (WRF) model development, another area of AFWA participation in supporting research. AFWA is closely collaborating with NCAR, NCEP, FSL, and the University of Oklahoma's Center for the Analysis and Prediction of Storms (CAPS) in WRF development. WRF is the next generation community model expected to replace MM5, and AFWA is benefiting by leveraging the efforts of more than 200 registered users developing the model. AFWA is preparing to fully implement WRF operationally in the 2004 to 2005 timeframe and will continue in 2002 with sponsorship and funding of development at NCAR and FSL, test and evaluation of real-time runs of the WRF prototype, and will lead the LSM Working Group while participating in others.

Atmospheric Optical Turbulence. Electro-optical (EO) systems are adversely affected by optical distortions caused by atmospheric thermal or refractive turbulence. As the sophistication of current and next generation military systems grows, the requirement for more detailed knowledge of 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. Researchers used a balloon-borne turbulence sensor mated to a standard radiosonde (Figure 3-DOD-4) to obtain measurements, producing data and empirical models that are the basis for ABL system specification. Balloon-borne measurements were made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum was 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 to assist in the development of the detailed knowledge to support new EO systems.

United States Weather Research Program (USWRP). AFW entered into discussions with USWRP in 2001 to explore expanded participation in the program and is looking forward to increased collaboration in 2002. USWRP's mission is to accelerate forecast improvements of high-impact weather and facilitate full use of advanced weather information. The program currently focused on landfalling hurricanes, heavy precipitation, and socio-economic impacts. AFW anticipates being able to leverage the advances made in the focus areas of landfalling hurricanes and heavy precipitation and is eager to leverage future efforts in the areas of observing and assimilation strategies in data sparse regions and urban forecast issues and opportunities. AFW is already committed to the USWRP-

Figure 3-DOD-4. An AF weather officer prepares a balloon for measuring atmospheric turbulence conditions as part of the airborne laser program. (US Air Force photo by Staff Sgt. Timothy Cook)

affiliated community development of the Weather Research and Forecasting (WRF) model and will continue to support this development during FY 2002. The basic WRF model is running at AFWA now and initial results are very favorable.

University Partnering for Operational Support (UPOS). AFW continued to collaborate through the UPOS program with the Johns Hopkins University Applied Physics Laboratory (JHU/APL), the University of Alaska at Fairbanks and its Geophysical Institute, and with the Army Research Laboratory (ARL). UPOS provides a link between university research and the DOD operational community and is currently focused on near-term forecasts of ground, tropospheric, ionospheric, magnetospheric, and solar weather. The goals of UPOS are to provide an alternate path for rapid transition of the best applied research ideas to the warfighter and to raise awareness of DOD operational needs within the academic community. The partnership delivers prototype operational products to the AF and Army sponsors. The UPOS Steering Committee, which includes the AF Director of Weather, meets approximately semiannually to review progress and select new projects as appropriate. UPOS includes warfighter exercise support to demonstrate utility of products through web-based, non-operational access as well as collecting direct user feedback for faster updates of the prototype systems. Some examples of tropospheric weather UPOS work include fine-scale polar numerical weather prediction, operational volcanic plume forecasting, and electromagnetic propagation forecast maps generated from MM5 output. Examples of space science work include high frequency radar and communication propagation to predict the area a transmitter can illuminate, forecasting coronal mass ejections, and improving determination of solar events which will cause militarily significant space weather effects on and near Earth.

Air Force Research Laboratory (AFRL). In other space weather research, AFRL programs focus 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, Digital Ionospheric Sounding Systems (DISS), the Improved Solar Observing Optical Network (ISOON), and the Operationalized Space Environment Network Display (OPSEND) 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. More detail on AFRL's space weather research is well documented in this section of last year's Federal Plan and this program will continue in 2002 to build improvements for future operational implementation.

In addition to the AFRL research portfolio, AFW collaborates with others in the space weather community to develop new techniques, models, and systems for transition to operational applications. These include the Community Coordinated Modeling Center, the Constellation Observing System for Meteorology, Ionosphere, and Climate, and the University Partnering for Operational Support mentioned previously.

Community Coordinated Modeling Center (CCMC). AFW is a full member of the consortium that formed the CCMC in 2000, co-chairs the CCMC Steering Committee, and supported center efforts in 2001 by providing Defense Research and Engineering Network (DREN) connectivity and exclusive access to a set of supercomputing nodes at AFWA. The CCMC mission is to provide a computing facility to enable, support, and perform research for the next generation of space weather models, preparing them for transition to operations through the rapid prototyping centers at both NOAA's SEC and the Air Force. The CCMC provides a place where researchers can try out space weather models in a large-scale computing environment, explore integration with other models, and structure their code to ease transition to operations. The center currently plans to deliver the first model, a 3-dimensional magneto-hydrodynamic magnetospheric model, to the rapid prototyping centers in September 2001. Sponsoring agencies are also planning a CCMC Workshop early in FY 2002 to explore future research activities for the center. AFW will continue to support the CCMC in FY 2002 but is examining alternatives to the increasing cost of maintaining the computing nodes dedicated to the CCMC. Additional information on the center is available at its web site at *http://ccmc.gsfc.nasa.gov/* (Figure 3-DOD-5).

Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC). AFW, through the Air Force Office of Scientific Research (AFOSR), will continue to collaborate with UCAR, NOAA, NASA, NSF, and the Navy on the COSMIC program. COSMIC comprises six micro-satellites planned for launch in 2005 to provide approximately 3,000 daily global observations of pressure, temperature, humidity, refractivity, ionospheric electron density, and ionospheric scin-

tillation. The system will use GPS occultation techniques to provide vertical atmospheric soundings as well as an ionospheric photometer and a triband beacon to measure electron densities and ionospheric parameters. The global coverage of atmospheric profiles should improve global-scale numerical weather prediction models as well as more limited value in regional models and point analysis models. The space weather observations will complement other sensors to provide a more complete picture of the ionosphere and improve prediction of communication and navigation degradations. Additional information on COSMIC is available at *http://www.cosmic.ucar.edu*.

In conclusion, through a continuous process of review and definition, the AF documents its requirements for supporting research aimed ultimately at providing timely, accurate, and relevant weather information to the warfighter today and in the future. In meteorological R&D, AFW is committed to continued development of the WRF model and collaboration with others to the benefit of the warfighter and the nation overall. Space weather research will continue with a strong program in 2002 both in AFRL as well as in leveraged programs such as UPOS and the CCMC to speed needed capabilities to operations at minimum expense.

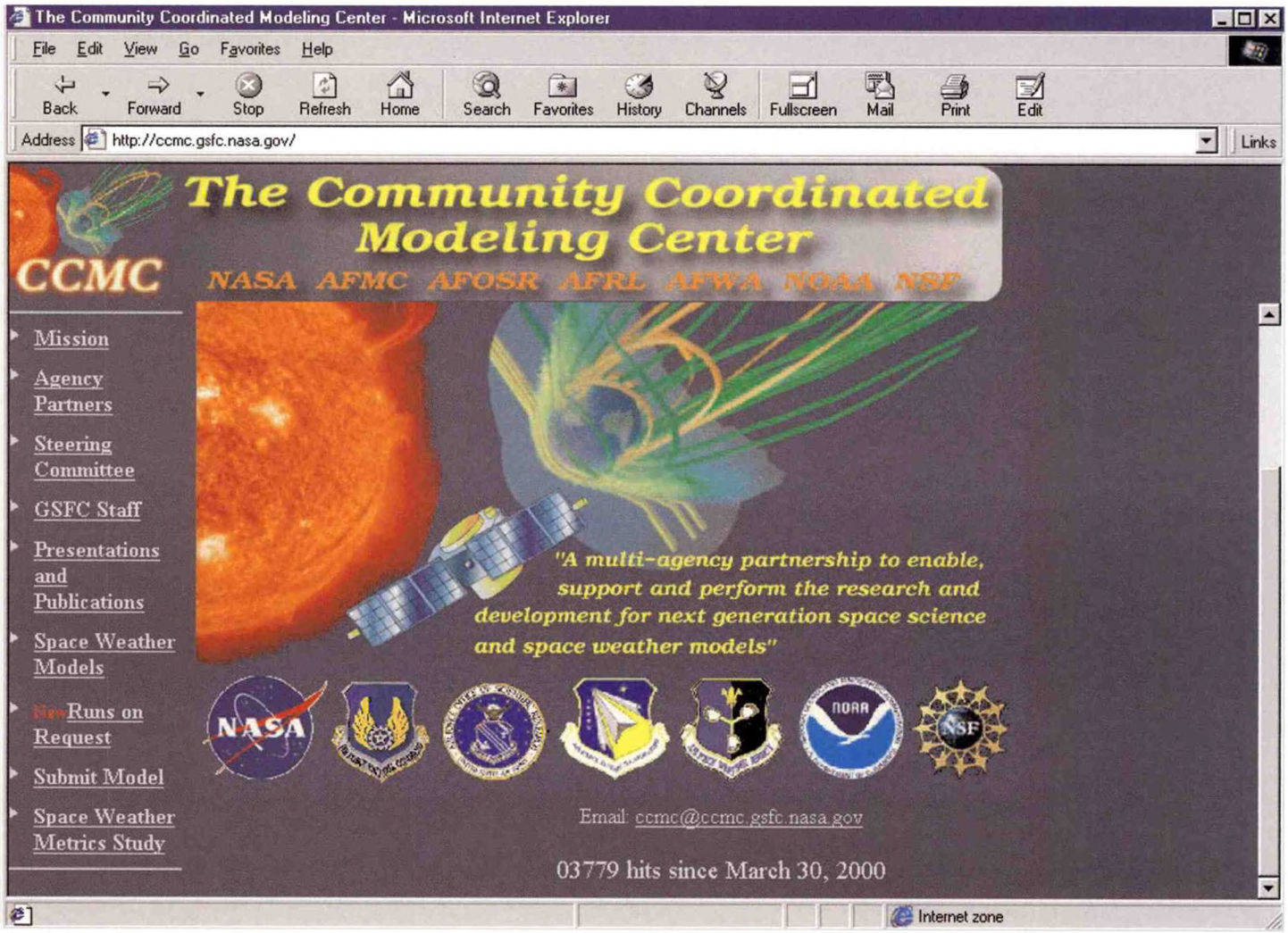
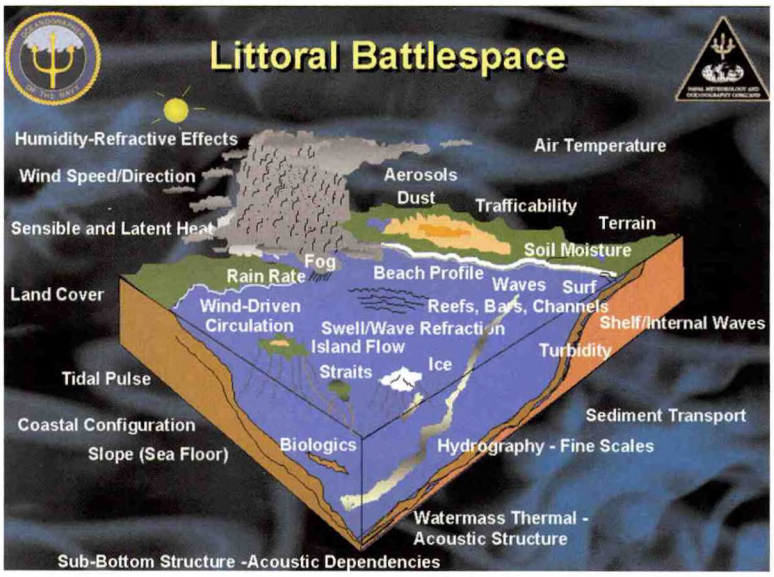


Figure 3-DOD-5. The home page of the Community Coordinated Modeling Center provides information on the center as well as access to research model output. (See text for URL.)

PROGRAM OVERVIEW

The United States Navy has the unique military requirement to assess meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations. METOC support begins by measuring the battlespace physical environment and culminates with safe, effective weapons systems and sensor employment. The perspective is global and historically focuses on areas outside of the contiguous 48 states, but the emphasis is wherever the fleet goes and includes force protection within the coastal waters of the United States. 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. Early in 2001, the Oceanographer of the Navy was named the "Navigator of the Navy." He serves as the Chief of Naval Operations' focal point for the development of technical standards for navigation plans, data standards, training, and navigation system certification. He also serves as an advocate and broker for all fleet navigation issues. The Oceanographer of the Navy also recently streamlined his staff's organizational structure to better respond to fleet needs. The Oceanographer of the Navy's websites are at *www.oceanographer.navy.mil* and (for navigation information) *www.navigator.navy.mil*.

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. To ensure that all research and development supported by the Oceanographer is in direct support of the Naval mission as established by formal Navy doctrine, the Oceanographer recently developed and implemented a comprehensive framework to transition research to operations. The Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARSYSCOM) are the primary activities that manage naval research and transition to operations, and are supplemented by 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 Oceano-graphic Office at Stennis Space Center, Mississippi. The SPAWARSYSCOM METOC Systems Program Office (PMW-155) is Navy's single program manager for METOC system development and acquisition.

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 (FLENUM-METOCCEN), in Monterey, California, provides global, regional, and tactical observations, analyses, and coupled air-ocean forecasts. Environmental data is acquired through links with DOD and National Oceanic and Atmospheric Administration (NOAA) conventional and remotely sensed data distribution systems. By agreement between Navy and Air Force, FLENUMMETOCCEN

Figure 3-DOD-6. Global locations for United States Navy theater and regional support

is the primary DOD global numerical weather prediction center, running the Navy Operational Global Atmospheric Prediction System (NOGAPS), developed by the Naval Research Laboratory's Marine Meteorology Division, also in Monterey. NOGAPS provides global atmospheric predictions and drives a variety of ocean models, including the global Wave Watch III ocean wave model run at FLENUMMETOCCEN.

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 with higher resolution and improved physics. In addition to the global product suite, FLENUMMETOCCEN is uniquely capable of providing high resolution coupled air-ocean 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 tactical system featuring data quality control algorithms; nested, non-hydrostatic physics; explicit moisture physics; aerosols; and improved data assimilation. Using lateral boundary conditions provided by NOGAPS, COAMPS provides a high-resolution, re-locatable, METOC prediction capability to support joint littoral operations. COAMPS is routinely run for Europe, Southwest Asia, Western Pacific, Central America, Western Atlantic, the continental United States, and the Eastern Pacific. COAMPS is frequently run in other areas around the world as requirements dictate.

NOGAPS and COAMPS forecast products are distributed via various communications systems including the Internet, 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. COMNAVMETOCCOM recently installed computer systems at all their 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, satellite products, 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 recently began disseminating products from the world's first operational global layered ocean model - NLOM. 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 scalable 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 (Figure 3-DOD-6). 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. Specific METOC products common to the regional centers include high winds and seas warnings for the world's oceans, tailored forecast support for Navy, Coast Guard and NOAA ships at sea, and ship routing services for ocean transits.

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. The detachments provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility (Figure 3-DOD-7). 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 AF and foreign products. Additionally, Fleet Numerical provides aircraft routing services for military (primarily Navy) aircraft on demand.

Two detachments provide specific technical services: one, at the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as part of the Federal Climate Complex. The detachment, at Tinker AFB, Oklahoma, manages Naval data requirements for the AF 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, aircraft and embarked personnel, optimum tactical and planning support to on-board 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. 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 METOC forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, United States Marine Corps (Code ASL37) is the cognizant office for Marine Corps METOC 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) (Figure 3-DOD-8).

Figure 3-DOD-7. SH-60 Seahawk rotors illuminated by sparks from blowing sands off Kuwait.

Figure 3-DOD-8. Marines launch reconnaissance craft from USS Austin (LPD 4) near Croatia. Small craft are especially susceptible to heavy seas.

Garrison aviation weather units at Marine Corps Air Stations (MCAS) and Facilities (MCAF) 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 (MAW). 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, and may augment a Marine Expeditionary Unit and Joint/Combined METOC Forecast Unit.

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) II Upgrade. The Primary Oceanographic Prediction System (POPS II U) operates complex computer-based models of the world's ocean and atmosphere and disseminates METOC forecasts, charts, imagery and operational data sets to support deployed Navy and DOD 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 II U 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 II U is the DOD approved system that operates global, regional, and tactical atmospheric, oceanographic, ice, wave, and tropical cyclone models (Figure 3-DOD-9). The POPS II U, located at FLENUMMETOCCEN also 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 II U is composed of a number of different high-performance computer systems, including a SGI Origin 3000 (512 processors) and two Origin 2000s (128 processors). By the end of Phase 1 (FY 2001), POPS II U will have replacement hardware and software that forms the basis of METOC support throughout DOD. This capability includes 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.

The POPS system performance improvement objectives will support DOD in the following specific ways:

a. Improved METOC forecast skill worldwide at increasingly longer time periods

b. Optimal aircraft routing services

c. Safe and direct ship routing services

d. Hurricane, cyclone, and tropical storm prediction worldwide

e. Open ocean and coastal wave prediction

f. Precipitation prediction
g. Refractivity conditions/ducting range
h. Acoustics support
i. Ballistic missile targeting support
j. Search and rescue
k. 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 is currently the nation's only military service that 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 is fielded at all Navy METOC centers worldwide and uses the COAMPS model to develop METOC prediction products out to 48-hours. DAMPS uses 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.

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 (MET) and USMC Meteorological Support Team (MST) METOC requirements. Fielding of NITES IV is expected to commence in FY 2003.
- 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.

Tactical Environmental Data Server (TEDS). TEDS is a storage and data management system for METOC information. It is the central engine in both the Tactical Environmental Support System (TESS) and the Navy Integrated Tactical Environmental System (NITES), providing the broadest support via access to the full spectrum of client applications and METOC models. TEDS architecture connects to government historical databases and commercial relational databases management systems (RDBMS) using network and Internet protocols. With the associated METCAST automated delivery software, users with Internet access can monitor information updates on demand, continuously, or on schedule.

Meteorological Data Receiver-Recorder (AN/SMQ-11). AN/SMQ-11 is the principal Navy system to acquire environmental data directly from satellites. There are different equipment configurations for ships and shore sites, and through their interface

Figure 3-DOD-9. USS KETCHIKAN (YTB 975) run aground by super typhoon in Guam.

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 (SWR) (AN/FPS-131 and AN/TPS-76). 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 non-Doppler 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 8x8x20 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, COAMPS and wave forecast data, are 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 (Figure 3-DOD-10). OTSR and OPARS save the operating forces of all services approximately $57 million per year in reduced fuel consumption and personnel costs.

The Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package originally developed in 1982 to make FLENUMMETOCCEN numerical products available to front line DOD users. All standard METOC fields, synoptic observations and basic DMSP satellite imagery is also available. NODDS has been made available to non-DOD Federal agencies and others in the civilian community through an earlier agreement between Navy and NOAA, but is now being phased out in favor of Web-based display capabilities.

The Joint METOC Viewer (JMV) is a more recent capability that is integrated into NITES and is gradually replacing 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 and other government sites including ships, and is available to authorized non-government users as well.

WxMAP ("Weather Map") is a new Web-based service from Fleet Numerical which allows military and civilian users worldwide to access numerical output of selected weather parameters at pre-established geographical areas throughout the world. Because of continually emerging Internet technology, a large subset of these products can also be made available to the general public at no additional cost.

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

Figure 3-DOD-10. Waves crash over the 65-foot-high bow of the aircraft carrier JOHN C. STENNIS (CVN 74).

(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 research and development (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 METOC 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 NOGAPS and the 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 hr) 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) between these two agencies was signed in 1993. Additionally, an agreement for shared processing of remotely sensed data was last updated in 1997. 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 NCEP.
- Navy/NOAA/Coast Guard operation of the National Ice Center.
- Cooperative efforts between FLENUMMETOCCEN and the Pacific Fisheries Environmental Laboratory of the National Marine Fisheries Service
- Air Force Weather Agency (AFWA)/Navy(FLENUMMETOCCEN, NAVOCEANO)/ NOAA-NESDIS agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement and installation.
- Satellite altimetry data processing.
- Training cooperation through Cooperative Program for Operational Meteorology Education and Training (COMET).

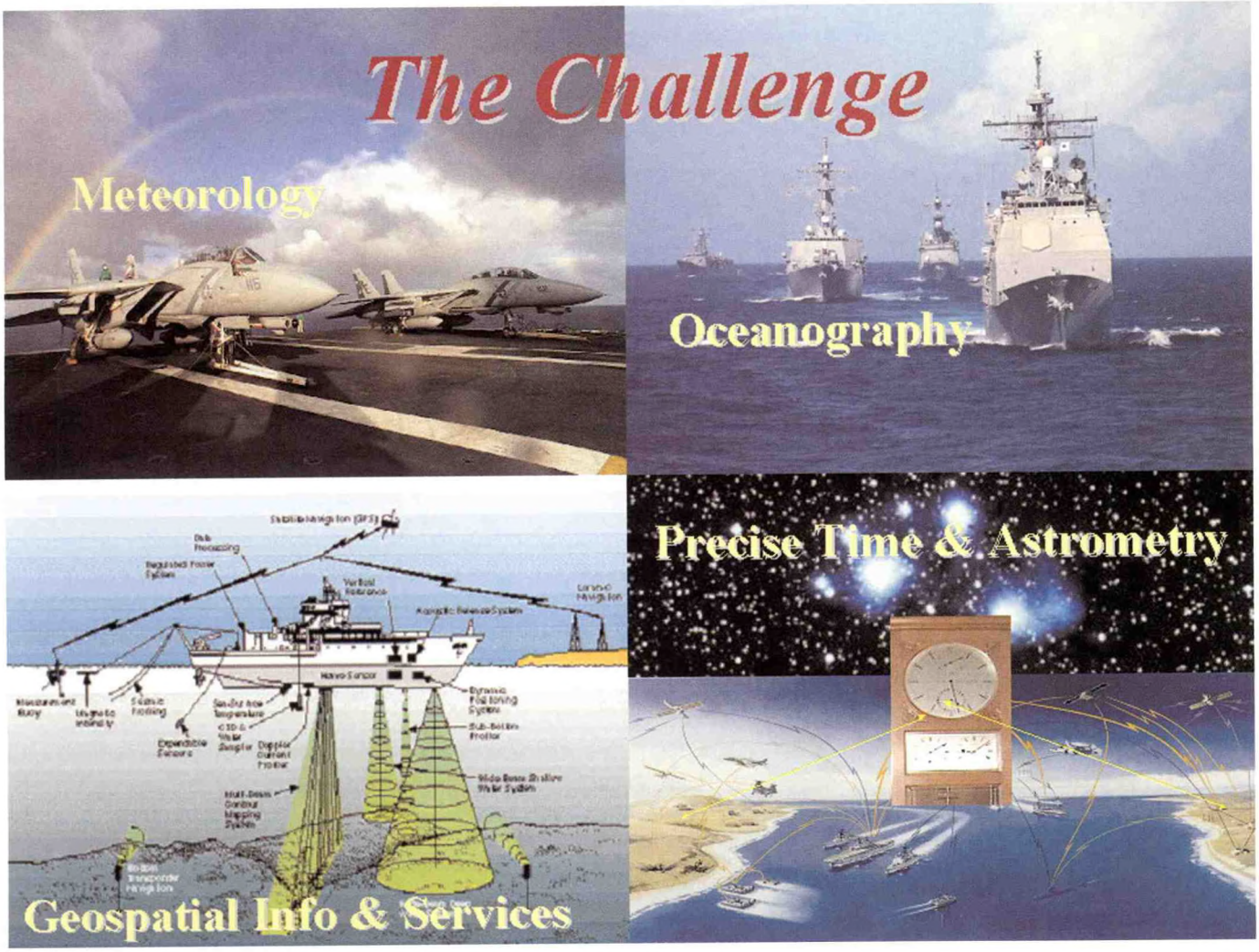
MOAs also exist between the Department of Commerce (DOC), Department of Transportation, and the DOD concerning procurement and operation of NEXRAD. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System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

COM activity when conditions warrant. For ships operating at sea without METOC personnel embarked, tailored enroute 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. 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. Storms of little consequence to the general public - those that remain well out at sea - are still of 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. Additionally, naval exercises and ship transits are often placed at risk by multiple tropical cyclone events, which can make successful evasion extremely difficult. Forecasts are provided to the fleet commanders and their staffs by the nearest NAVMETOCCOM activity. Within CONUS and adjacent ocean areas, tropical cyclone forecasts in particular are closely coordinated with those of the National Weather Service. Overseas, local tropical cyclone warnings and forecasts are based on guidance provided by the Joint Typhoon Warning Center, Pearl Harbor, Hawaii.



ARMY TRANSFORMATION

Global changes to the strategic environment dictate that the Army significantly alters the way it conducts business (Figure 3-DOD-11). On 12 October 1999, the Secretary of the Army and the Chief of Staff of the Army articulated a Vision designed to posture the Army so that it can better meet the demands of the 21st Century: "Soldiers on Point for the Nation...Persuasive in Peace, Invincible in War." The requirement to transform the Army is based upon emerging security challenges in the 21st Century as well as the requirement to respond more rapidly across the full spectrum of operations. In support of the National Security Strategy (NSS), the strategic significance of land forces lie in their ability to not only fight and win our Nation's wars, but also to provide options to shape the global environment to the future benefit of the United States and its allies. To this end, the Army developed a strategy and plan to guide this transformation.

Figure 3-DOD-11. The United States Army Strategic Environment.

The Army Vision is about People, Readiness and Transformation. People are the centerpiece of our formations; leadership is our stock in trade. It is imperative that we continue to take care of our quality soldiers, civilians, veterans and their families as we transform our Army. Readiness remains, as it has always been, our top priority. We have a non-negotiable contract with the American people - to fight and win the Nation's wars. We must ensure that at all times, the Army can meet demands of the National Military Strategy and requirements specified in the Joint Strategic Capabilities Plan (JSCP). Finally, the Army must transform, to become more strategically responsive and dominant at every point on the spectrum of operations.

The vision represents goals for the Army, while Transformation and its accompanying Transformation Campaign Plan (TCP) are vehicles for becoming more strategically responsive and dominant. Achieving the vision requires a complete transformation of the entire Army.

Transformation consists of three major objectives: Initial Force, Interim Force and Objective Force, with three corresponding phases (Figure 3-DOD-12). The first phase of Army Transformation has already begun. During this phase, the Army is fielding an Initial Force of two Brigade Combat Teams at Fort Lewis, Washington. During FY 2000-01, these two units will establish and validate an organizational and operational model for Interim Brigade Combat Teams. To bridge the gap between the capabilities of today's force and the Objective Force, it is necessary to field an Interim Force of six to eight brigades, employing the Interim Armored Vehicles (IAVs) and currently available off-the-shelf equipment. These Interim Brigade Combat Teams (IBCTs) will be the vanguard of the future Objective Force - they will have full spectrum capability and be available for apportionment to the warfighting CINCs. These Interim Brigades will also have the capability to deploy anywhere in the world in 96 hours. The Army envisions fielding the first units of the Objective Force in eight to ten years. This force will not only retain the capability to deploy a combat-capable brigade anywhere in the world in 96 hours, but also a division in 120 hours and five divisions in 30 days. The Objective Force will provide the National Command Authority (NCA) with an increased number of options for regional engagement, crisis response and sustained land force operations. The Objective Force is designed around a Future Combat System (FCS) that will incorporate state of the art technologies and capabilities into a multi-mission combat system. The Army has significantly increased spending in Science and Technology in order to develop the operational capabilities of the FCS and the overall force. Throughout the transformation, readiness remains our top priority - the Legacy Force provides this capability. The Army must fulfill its non-negotiable contract with the American people-to fight and win the Nation's wars. Therefore, the Army must sustain and recapitalize its Legacy Force to guarantee mainte-

nance of critical warfighting readiness. To accomplish this, the Army will recapitalize selected legacy formations, in its Active and Reserve Components, to enhance key armored and aviation systems, as well as enhance light force lethality and survivability.

These changes to the Army structure dictate changes in both weather support requirements and the way weather is provided to the new Brigade Combat Teams. Weather teams will be smaller in size and will depend more heavily on "reach back" capabilities to obtain meteorological data. The United States Air Force (USAF) is working with the Army to optimize the type and level of weather support that will be provided to the new brigades, while still maintaining appropriate support to the legacy force during transformation.

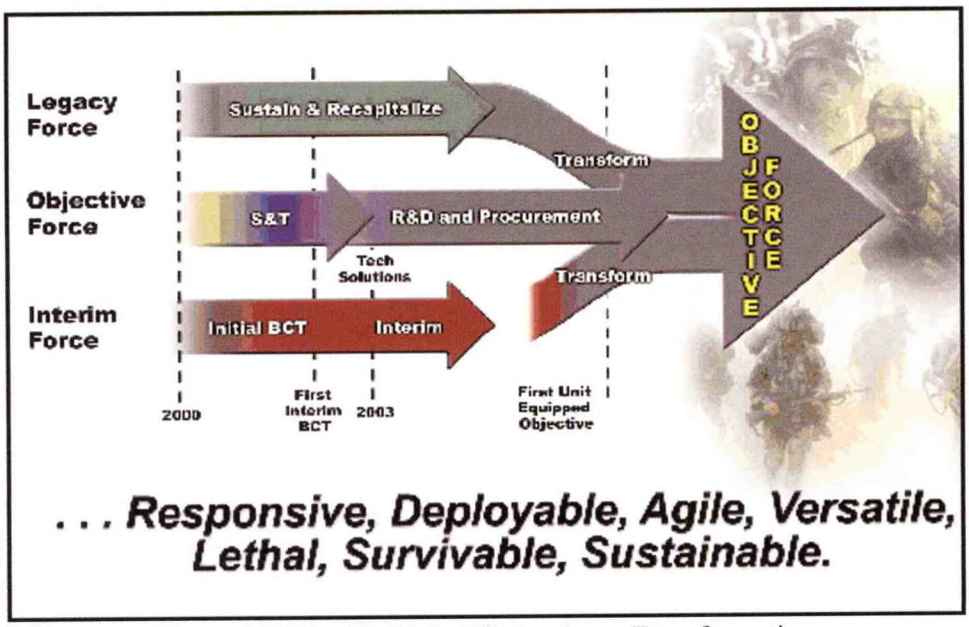


Figure 3-DOD-12. United States Army Transformation.

ARMY OPERATIONAL AND MISSION SUPPORT

United States Army weather support is a mix of Army and USAF personnel and equipment under Law and according to Army-Air Force (AF) agreement. Army Regulation (AR) 115-10/AF 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-13). 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 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) 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.

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 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 Multi-purpose 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 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 AFW Agency (AFWA) 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 active component (AC)/RC 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. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army Integrated Meteorological System (IMETS) is fielded for these purposes and is operated by 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).

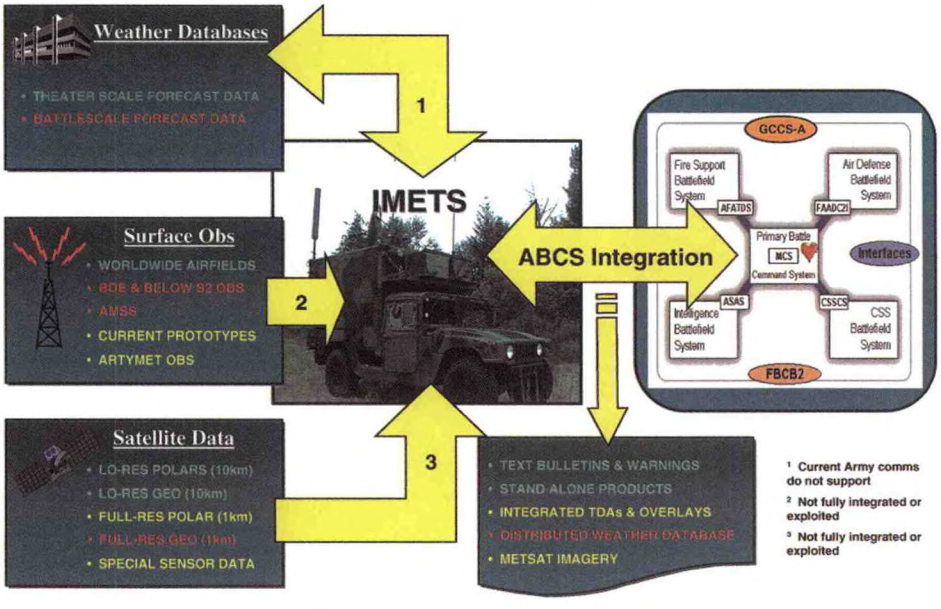


Figure 3-DOD-13. Army Weather Support Architecture.

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 MMS to collect upper air observations for direct use by field artillery units. ARTYMET crews also collect upper air observations for training; these observations are available to the 607th Weather Squadron (607 WS) upon request.

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 USAF weather teams supporting Army air, ground, or special operations. These observations are used by forecasters at the 607 WS Theater Forecast Unit (TFU) to accurately predict mission limiting weather in the demilitarized zone (DMZ).

The USAF will use new automated COTS observing systems at 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 607 WS TFU. They will also be incorporated into the global weather database to improve short term forecasting in the northern ROK. There are plans to buy more automated COTS sensors in FY 2002, for use along the DMZ and in the northern ROK.

USAF weather personnel assigned to the 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. The 607 WS TFU took over forecasting responsibilities for the eight EUSA locations in FY 2000, and is responsible for terminal aerodrome forecasts, along with weather advisories and forecasts for these locations. The EUSA CWTs are primarily responsible for providing their customers with observations and tailored support. 607WS 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.).

United States Army In Europe And Seventh 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 (7 WS) provides USAREUR/7th Army in-garrison and tactical weather intelligence and support. This includes observing services for in-garrison operations, contingency and exercise operations, staff weather officer (SWO) services, and specialized support. The United States Air Forces in Europe (USAFE) Operational Weather Squadron (OWS) at Sembach AB, Germany, provides operational-level forecast products for the European Command Area of Responsibility, to include all USAREUR units (Figure 3-DOD-14). Combat weather teams located at V Corps and its aviation assets, 1st Infantry Division and its aviation brigade, 1st Armored Division and it aviation brigade, evaluate and tailor these forecast products to produce mission execution forecasts.

The mission of 7 WS and its ten detachments is to provide weather operations packages to conform to the Army's Transformation initiative. 7 WS will match the deploying weather force structure to the mission that USAREUR is called upon to execute. 7 WS will utilize "reachback" capabilities to the maximum extent possible to minimize the deployed footprint without compromising weather operations.

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 TV-SAT, NIPRNET and SIPRNET. Units also use the NATO Automated Meteorological Information System (NAMIS) to receive NATO generated

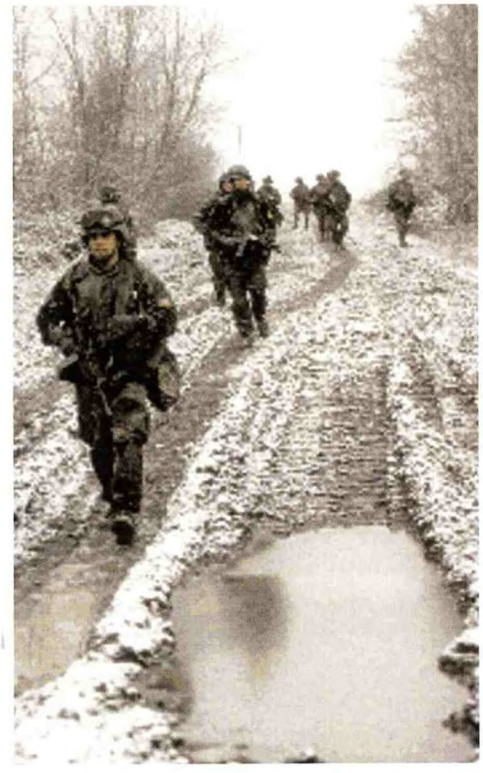


Figure 3-DOD-14. United States Army Soldiers on partol in Bosnia.

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 Integrated Meteorological Systems (IMETS) have been fielded within USAREUR, with two more programmed for FY 2002. Five Portable Automated Observing Systems (PASOS) and Portable Weather Radar are deployed to Task Force Falcon (TFF), Kosovo, with an additional PASOS unit currently being installed.

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

United States Army Special Operations Command (USASOC)

Weather support to USASOC consists of forecasts and observations, climatological studies and course of action recommendations to aid commanders in improving efficiency, effectiveness, and safety of operations for USASOC units. USASOC personnel provide limited scope meteorological observations in direct support of Army operations using tactical weather kits to collect limited weather data 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 AF Special Operations Command (AFSOC) and ANG weather personnel. AFSOC and ANG weather personnel supporting USASOC are assigned to the 10th Combat Weather Squadron (CWS), OL-A, 320 Special Tactics Squadron (STS), OL-A, 321 STS and the 107th, 146th, and 181st ANG Combat Weather Flights (CWF's). These weather units provide garrison and tactical support to USASOC units including the 75th Ranger Regiment and subordinate battalions, the 160th Special Operations Aviation Regiment, seven Special Forces Groups and subordinate battalions and two Psychological Operations Groups. Support provided includes 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 Army Special Forces Command (Airborne), and the United States Army John F. Kennedy Special Warfare Center and School. USASOC provides supporting AFSOC and ANG units with required facilities, equipment, and operating funds (for expendables, maintenance, etc.).

United States Army Pacific (USARPAC)

USARPAC uses 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 surface weather observations to support tactical units and operations.

USARPAC provides supporting USAF units with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operations and maintenance funds.

The IMETS and New Tactical Forecast System (NTFS) have been fielded within USARPAC as the primary meteorological equipment for deployed operations. The IMETS and NTFS reachback for data via Army provided NIPRNET and SIPRNET conduits. Deployed weather teams also use the Small Tactical Terminal (STT) for direct reception of weather satellite imagery.

In FY 2001 the 17th Operational Weather Squadron (17 OWS) was activated, as part of ongoing reengineering and realigning. The 17 OWS provides CWTs within its area of responsibility with garrison and tactical weather warnings, forecasts, special support, and Staff Weather Officer (SWO) services during contingencies and humanitarian operations. Additional CWTs assigned to United States Army Japan (USARJ), 25th ID and 172nd SIB provide direct, on-site support at five USARPAC installations. The CWTs also deploy with their customers providing tailored battlefield observations and forecasts. Weather reengineering will reduce the requirement for forward deployed weather personnel, and instead leverage IMETS and other recently fielded technology. The 17 OWS, through reachback, will provide regional weather support, allowing the forward-deployed forces to focus on specific area and target forecasts.

United States Army Forces Command (FORSCOM)

Weather support to the United States Army Forces Command (FORSCOM) is diverse and demanding. FORSCOM is the Army's largest major command and requires and uses 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. FORSCOM consists of more than 760,000 Active Army (AA), United States Army Reserve and ARNG soldiers. These soldiers account for around 85 percent of the Army's combat power. FORSCOM trains, mobilizes, deploys, and sustains combat ready forces capable of responding rapidly to crises worldwide. The AA of FORSCOM has nearly 200,000 soldiers. Third

United States Army is the Army component of United States Central Command (USCENTCOM), the Joint command responsible for Southwest Asia (SWA) and the Horn of Africa. FORSCOM also commands two Army Corps: III Corps at Fort Hood, Texas; and XVIII Airborne Corps at Fort Bragg, North Carolina. Together they include six divisions, two armored cavalry regiments, five separate brigades, and a range of other corps combat, combat support and combat service support units. The two Continental United States Armies (CONUSAs), First United States Army and Fifth United States Army, are responsible for training, mobilization and deployment support to Reserve Component units in FORSCOM.

A major subordinate command of FORSCOM, the United States Army Reserve Command (USARC) commands all United States Army Reserve units in the continental United States, except those assigned to Special Operations Command. FORSCOM's Army Reserve strength stands at about 196,000 soldiers. USARC units are part of the Federal force and make their primary contribution to FORSCOM combat power in combat support and combat service support specialties such as medical, civil affairs, transportation, maintenance and supply.

The ARNG provides FORSCOM a balanced force of eight National Guard combat divisions, 15 enhanced separate brigades, and extensive combat support and combat service support units. The current FORSCOM ARNG strength is approximately 367,000 soldiers.

United States Army Signal Command also falls under control of FORSCOM and provides all Echelon Above Corps (EAC) tactical, power projection, and strategic signal support to warfighting unified commanders, as well as Army component commanders, in both war and peace.

Weather support to FORSCOM's AA units comes from dedicated AF weather teams aligned under three Air Support Operations Groups (ASOGs): 1st ASOG at Fort Lewis, Washington; 3rd ASOG at Fort Hood, Texas; and 18th ASOG at Pope AFB, North Carolina. A weather squadron for each ASOG makes up the Corps combat weather team (CWT). Each Army division has their own dedicated CWT. These CWTs are aligned under an Air Support Operations Squadron (ASOS) or one of the weather squadrons, at their respective installations. Corps and division CWTs are authorized enough personnel and equipment to support a variety of missions at the various Army echelons. Weather support at each Army echelon is provided according to Army Field Manual 34-81/AF Joint Pamphlet 15-127, Weather Support for Army Tactical Operations. Currently, there are nearly 350 AF weather authorizations supporting various echelons across FORSCOM. These AFW personnel provide garrison and tactical weather warning, observing, forecast, special support, and staff weather officer (SWO) services during contingency, exercise, or armistice operations.

FORSCOM weather units provide direct, on-site support at 11 major installations, including the National Training Center at Fort Irwin, California, and the Joint Readiness Training Center at Fort Polk, Louisiana and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions.

FORSCOM provides supporting USAF units with a Modified Table of Organization and Equipment (MTOE) and operating funds (expendables, maintenance, etc.). Eleven artillery meteorological (ARTYMET) sections collect upper air observations for direct use by field artillery units. The Forward Area Limited Observing Program (FALOP) consists of Army personnel taking limited observations at forward areas in the battlespace.

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. Satellite imagery (METEOSAT and DMSP) is received via the Small Tactical Terminal (STT). Nineteen IMETS have been fielded within FORSCOM. Two Automated Surface Observing Systems (ASOS) with one located Yakima Training Center and the other a Camp Doha, Kuwait.

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. A key mission area for the next few years will be to coordinate Army weather support requirements during AFW Reengineering and Army Transformation. Deployed weather support will improve significantly with the digitization of these experimental Army units. Customized battlefield weather "visualizations" transmitted via the Integrated Meteorological System (IMETS) will take the place of the stand-up weather briefings of the past. The results of the Advanced Warfighting Experiments (AWEs) will show us 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.

Weather Support Process

TRADOC schools submit requirements for weather support to HQ TRADOC for approval. Upon concurrence, HQ TRADOC normally states requirements for USAF support to HQ, Air Staff - Director of Weather, for solution/implementation. Requirements for Army-provided communications or tactical equipment are submitted through ODCSOPS to prioritize and program resources.

The United States Army Intelligence Center and Fort Huachuca (USAIC&FH) is the Army's functional proponent for tactical weather support. The Weather Support Team (WST) advises the Commanding General of USAIC&FH, ARL, and AFW on Army-wide weather support requirements and known deficiencies. They frame requirements to meet both active and reserve force needs. They assist in training development for AFW personnel supporting the Army (i.e., the Staff Weather Officer Army Indoctrination Course), as well as training Army leaders to leverage weather intelligence on the battlefield (Figure 3-DOD-15). With dwindling resources and personnel reductions, the team has sought solutions that are compatible with AFW Reengineering plans and that maintain quality weather support to the Army warfighter. The USAIC&FH WST currently consists of an AF Staff Weather Officer, one senior AF Noncommissioned Officer, plus other USAIC&FH intelligence analysts and combat developers on a task-organized basis.

The Staff Weather Officer at the United States Army Combined Arms Center facilitates modifications to the Tables of Organization and Equipment 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.

The Schools and Battle Laboratories

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 MMS, AN/TMQ-41 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.

Figure 3-DOD-15. Ft. Drum Weather Team at the Joint Readiness Training Center.

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.)

In 1999, the Army Military Police and Chemical Schools moved to Fort Leonard Wood. Neither currently employ staff meteorologists.

The Aviation Center at Fort Rucker incorporates weather instruction and procedures into rotary-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.

Army National Guard Artillery

The ARNG has 48 Meteorological Sections assigned to artillery units at Division level, Field Artillery

Brigades, and in Separate Brigades. The ARTYMET sections provide upper air observations at least 39 training days each year supporting artillery live fire during Annual Training and monthly Inactive Duty Training. The ARTYMET sections support an average of 20 live fire training days and annually expend in excess of 100 balloons per section. The ARNG is in the process of modernizing to the MMS, AN/TMQ-41A. Active component fielding of Profiler will facilitate continued modernization through the cascade of MMS to the ARNG.

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, temperature. Meteorological data represents only about ten percent of the COE's gauging program funding. Most gauging stations include hydrologic measurements for surface water runoff, water quality and sediment. 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 (USGS) to maintain precipitation data collection from 500 sites, while the COE maintains the rest. Eight-two percent of all Corps sites provide real-time via satellite microwaves meterbursts, landlines or radio. Data from all COE networks are available and used by other federal, state and local agencies, and are extensively used by NWS and USGS to support their programs.

United States Army Space and Missile Defense Command (USASMDC)

Army Space Command (ARSPACE), a SMDC component, provides operational space weather support on a limited basis to Army units through it's Army Space Support Teams (ARSST) as well as Space Operations Officers (FA40). ARSST teams and FA 40s' provide space weather support to the warfighter through an Army - AF agreement where ARSPACE will provide space weather support until an appropriate number of AFW personnel are trained in space weather and assume the mission. Space weather support is provided to Army warfighters as part of ARSPACE's effort to improved overall space support and situational awareness. Potential space weather effects including disruptions of over the horizon communications, radar interference, space environment induced satellite service disruptions, high flyer radiation hazards and hazard warnings to civil power grids resulting from geomagnetic activity.

Related projects include the annually updated Space Weather Smart Book that is intended to improve the ARSPACE staff, ARSST teams and FA 40s understanding of space weather fundamentals. In addition, ARSPACE is developing a Space Intelligence Preparation of the Battlefield (SPACE-IPB) visualization tool that will include a visual depiction of scintillation (disturbed ionosphere) conditions over a given operational area.

ARSPACE provides space weather support through a .5 staff year contract valued at $53,000. There has been no change in funding levels between FY 2001 and FY 2002.

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.

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 Materiel 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; Arlington, 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), Arlington, 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 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 (MMW) 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.

Army Matériel Command (AMC)

The Army Matériel 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 Army Research Laboratory (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, (3) for the Materiel Developer to minimize system weather impacts, supplying atmospheric effects information and (4) increase the battlefield situational awareness by accurately assessing environmental effects. The joint Army/AF "*Own The Weather*" initiative provides the knowledge of current and forecasted battlefield environmental conditions, along with their effects on systems, soldiers, operations, and tactics, to contribute to achieving 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, atmospheric effects on acoustic and electro-optic propagation, 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 reprogramming to respond to the new AFW 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 Integrated Meteorological System (IMETS), and works with the AFWA and Combat Weather Center to

make IMETS an integral part of the total battlefield weather support mission.

The BE Division within the ARL Computational and Information Sciences Directorate, consists of four Branches, two each at the ARL primary side at Adelphi, Maryland, and the White Sand Missile Range, New Mexico. These four branches combine basic research programs focused in the areas of chemical/biological transport and dispersion theory, and in-depth understanding of the meteorological processes inherent in the planetary boundary layer, with an applied research development program focused on transitioning of products for Army tactical operations. 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 is able to 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.

At the Weather Exploitation Branch, located at the White Sands Missile Range location, research and development 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^{4}I 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 Fort 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 Advanced Warfighting Experiments (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 delivered for integration to the other C^{4}I tactical systems operating under the Army Battle Command System, version 5.0 (ABCS 5.0). 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 AFW 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 Integrated Weather Effects Decision Aid (IWEDA) have been assembled jointly across the services to provide a common rule-base for weather impact decision aids.

The Artillery Meteorology Branch, also located at the WSMR site, combines a research and development program that focuses on the means to measure, process, analyze, and predict atmospheric conditions in target areas for fire support and related Army activities. Technical expertise and support is provided directly to the PM NV/RSTA and PM TESA in the design and development of the Engineering Manufac-turing Development (EMD) Profiler system. Research is being focused on developing new algorithms for the retrieval of meteorological parameters and profiles that will lead

to the ability to process meteorological data at rates approximating real-time. Research is also underway in enabling technologies that will permit the handling and transfer of large met data sets over the distributed, net centric force of the future.

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 Logistic Readiness Center is the level II manager of the MMS program. It is supported by the Information and Intelligence Warfare Directorate and other internal organizations in developing and fielding weather support systems. CECOM also provides support to 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, MMS-Profiler (MMS-P), and the Integrated Meteorological System (IMETS). A brief description of each of these programs shows CECOM's involvement.

Meteorological Measuring Set, AN/TMQ-41. 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). All active Army units are equipped with the MMS. Additional systems to modernize the National Guard were begun in FY 1999 and will continue through FY 2002. In FY 2001, the Army bought an additional 14 systems. More systems are anticipated as being bought in FY 2002.

Meteorological Measuring Set-Profiler, AN/TMQ-52 System. The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. The AN/TMQ-52 designed to support the new generation of artillery weapons. It will provide more frequent messages with validity over a larger battlespace than current equipment. The MMS-P uses the MM5 mesoscale meteorological model to assimilate data from a variety of sources to provide the best meteorological messages to the user in a timely fashion. The system receives data from ground-based sources, from radiosondes, and from satellite-based sources, such as boundary data from communications and polar orbiting meteorological satellites, through on-board satellite receiving capability. The data is used to affect the operation of the mesoscale meteorological model and for post-processing of the data so that all the required meteorological messages can be generated. Finally, an operator interface, in conjunction with the message generation and formatting software, facilitates communication between the MMS-P and all other systems that require interoperability with the MMS-P. Currently in development are four Engineering and Manufacturing Development (EMD) models. Development and testing will be accomplished during FY 2001 and FY 2002, with testing and a production decision scheduled for FY 2003.

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

AFW 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 2002 efforts will focus on four main areas. The Army will field one AN/TMQ-40C vehicle mounted configuration and complete the upgrade of twenty fielded IMETS from AN/TMQ-40A's to AN/TMQ-40B. The Army will also hand-receipt a second IMETS Light to the IBCT and will conduct an IMETS Light combined developmental and operational test in order to achieve a Milestone III decision for fielding this configuration.

Army Test and Evaluation Command (ATEC)

The Developmental Test Command (DTC), a subordinate command of United States Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to eight Army ranges and test sites. Under responsibilities established in AR 115-10/ AFJI 15-157, the DTC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support Army and other DOD research, development, test and evaluation (RDT&E) activities at the eight Army installations. Funding for the Army RDT&E Meteorology Program under Program Element 665702 has stabilized after several years of decline and is sufficient to maintain the basic meteorological support infrastructure at Army RDT&E ranges and sites. However, instrumentation needed to support unique or test-specific requirements generally must be funded by test sponsors.

The Army RDT&E Meteorology Program has entered into a multi-year working relationship with the National Center for Atmospheric Research (NCAR) to enhance "range scale" (mesoscale to microscale) forecast and analysis technology. The principal product of this relationship is the Four-Dimensional Weather (4DWX) System, which consists of a central data archival/retrieval system for all range and external meteorological and model data, a high-resolution mesoscale meteorological model, and a variety of user-configurable displays. The MM5 mesoscale model is used operationally in both predictive and analysis modes to provide detailed information about the past, current, and forecast structure of the atmosphere over the Army's test ranges. Output from both MM5 forecasts and analyses is used as meteorological input to atmospheric dispersion, noise propagation, ballistic trajectory, and other range applications models to simulate many tests and their associated impacts. The 4DWX system contributes to improved test planning and conduct, selection of more representative locations for test sensors, inclusion of realistic atmospheric effects in virtual testing, and forensic analyses of meteorological effects on test results.

The Chief of the Meteorology and Obscurants Division at Dugway Proving Ground's West Desert Test Center serves as the Program Manager for Meteorological Support to Army RDT&E. Under Program Element 0605384, the Division's Modeling and Assessment Branch also provides the following specialized services: (1) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; (2) chemical/biological threat analysis, detection, and decontamination tests and studies for the Joint Contact Point Project (DO49); and (3) prototype development of virtual proving ground meteorological support. Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, and chemical/biological hazard assessment.

Army Medical Research and Matériel 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 Operational Medicine Environmental Grid Applications (OMEGA) project is a software development effort intended to provide an integrated research platform for the evaluation of predictive modeling strategies for warfighters. It enables the integration

of digital terrain data and real-time weather information with candidate physiologically-based environmental injury risk and performance prediction models. This test-bed system has a field of view of up to 200x200 km and uses a color-coded map overlay display format. The web-enabled client-server architecture and archiving resources of OMEGA are intended to provide a rich and extensible tool set for model development efforts at USARIEM and to contribute key modeling methodologies directly to other projects.

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 military clothing types and work categories.

As part of the warfighter physiological status monitoring (WPSM) program, USARIEM is investigating methodologies needed to integrate real-time local environmental data and warfighter physiological data with predictive model processes. The effective fusion of these two real-time data streams will enable near term environmental strain and performance status predictions for individual warfighters. Research efforts in this area are intended to address capabilities identified in the Operational Requirements Document (ORD) for the Army's Land Warrior program.

The availability of ground level environmental data at high temporal and spatial resolution continues to pose a significant challenge for predictive model development and validation. A Phase II Small Business Innovative Research (SBIR) project to design and build a very small wireless network-capable, expendable, micro-environmental sensing system is underway, 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 Federal Railroad Administration is promotes and regulates railroad safety. It also sponsors research to enhance railroad safety and efficiency, including support for improved collection, dissemination, and application of weather information to reduce hazards to train operations and to railroad employees. The Federal Transit Administration mission is to ensure personal mobility and America's economic and community vitality by supporting high quality public transportation through leadership, technical assistance and financial resources. 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. As the leader, FAA must conduct continual coordination for identifying needs for aviation weather products and services among the Air Traffic Control organization, the aviation industry components and among service providers. The coordination process leads to opportunities to leverage efforts and resources to form partnerships in finding solutions in response to the needs. The *National Aviation Weather Program Strategic Plan* and The *National Aviation Weather Initiatives* are two documents that formalize the coordination and partnerships.

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 evaluate the series of events leading to investigated accidents, and get a sense for what decisions were made in the course of the flight. Other teams, using the findings of the first team, develop intervention actions to eliminate or reduce the causes or improve the actions in the decision making process. Training about the decision making process has been identified by these teams as part of the solution.

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 multi-media training tools to support aviation safety and training initiatives. Funding has been requested to further this effort.

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 FAA 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 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. ARS has added improvements to the AMS process whereby non-system or non-hardware (e.g. service improvement or rule changes) solutions will receive the same rigorous evaluation and validation.

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 ARS, clarifying FAA lines of business, and completing intra-agency and inter-agency 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. All agencies' efforts in the area of aviation weather services is coordinated for use by all as appropriate. Aviation weather technology includes the ways in which aviation weather information is gathered, assimilated, analyzed, forecast, 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 aviation weather information through integration of federal and non-federal resources. Automation, improved product generation, and dissemination to the cockpit offer early opportunities.

AVIATION WEATHER ACQUISITION AND SERVICES

One of the primary functions of the FAA ARS organization is the development and management of requirements for the FAA Capital Investment Plan. Recent projects in the AMS 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 many of those projects.

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 38 ITWSs which will provide displays at 47 high activity airports that are supported by terminal Doppler weather radars. Full production is expected by early calendar year (CY) 2001 (Figure 3-DOT-1).

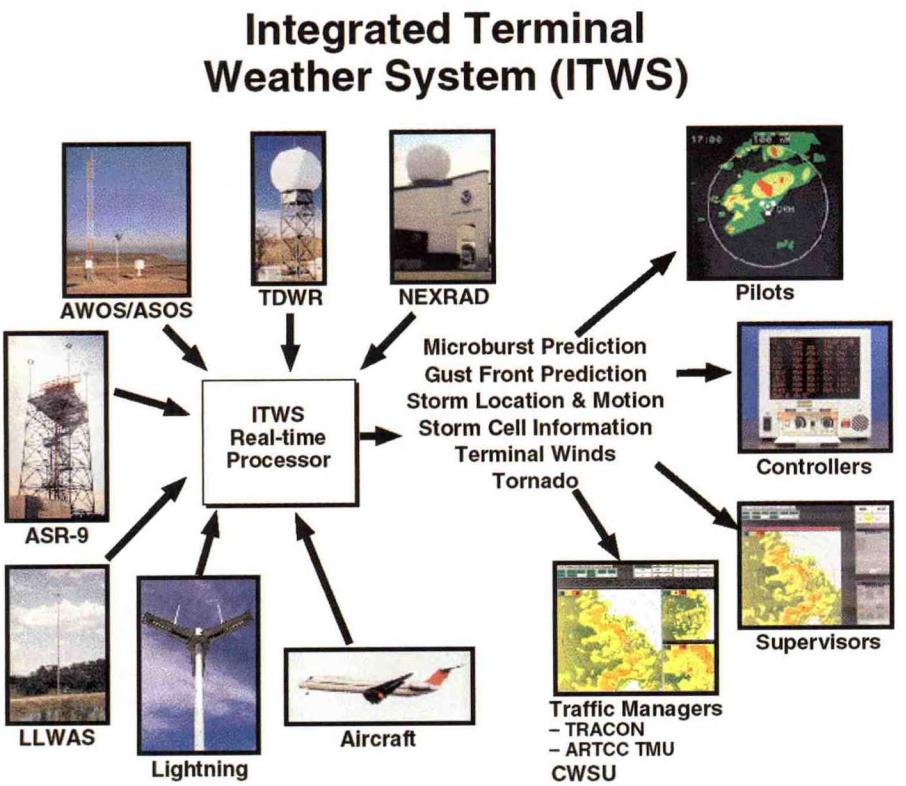


Figure 3-DOT-1. The ITWS will integrate data from FAA and NWS sensors and systems to provide a suite of weather informational products.

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

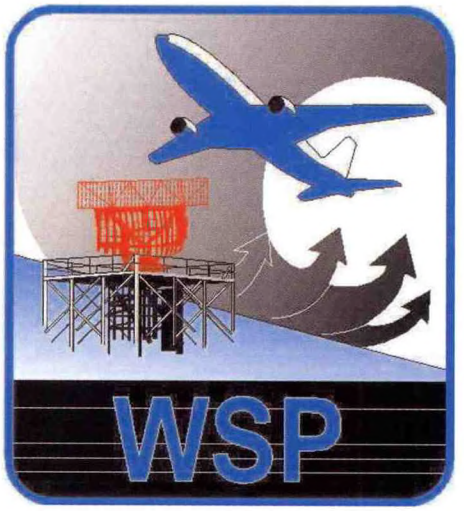
The Terminal Doppler Weather Radar (TDWR) program consists of the procurement and installation of a new terminal weather radar based on Doppler techniques. TDWR units have been located to optimize the detection of microbursts and wind shear at selected high activity airports. In addition, it has the 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 is optimized for microburst/wind shear detection. The radars are located near the airport operating areas in a way to best scan the runways as well as the approach and departure corridors. The displays are located in the tower cab and Terminal Radar Approach Control (TRACON).

FAA has 45 TDWR systems commissioned and the remaining 2 systems will be commissioned by the end of FY 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 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 to 32 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 being deployed in CY 2001and the remainder by mid FY 2003.

The Weather Systems Processor (WSP) program provides an additional radar channel for processing weather returns and de-alias returns from the other weather channel in the ASR-9. The displays of convective weather, microbursts, and other wind shear events will provide information for controllers and pilots to help aircraft avoid those hazards. A prototype has been demonstrated and limited production has commenced. Full production deliveries are expected to be completed in FY 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 47 TDWR systems will be deployed with 45 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.

The Flight Information System (FIS) Policy was implemented during FY 2001, through Government-Industry Project Performance Agreements (G-IPPAs) with two industry FIS data link service providers (ARNAV Systems, Inc. and

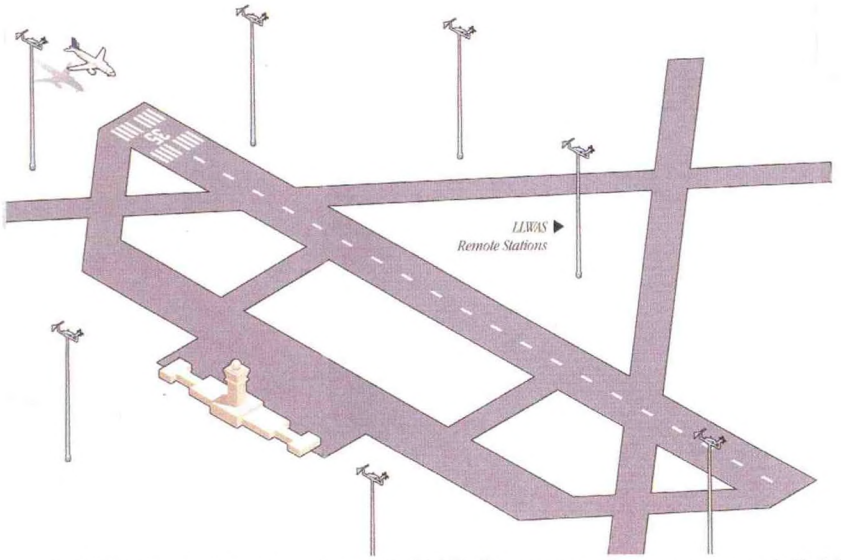


Figure 3-DOT-3. Artists drawing of LLWAS tower positions on an airfield.

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 establishing a national capability for collecting and distributing electronic pilot reports (E-PIREPs) from low-altitude general aviation operations is being 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

Aviation weather observations. 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.

Automated Weather Observing Systems (AWOS) was deployed 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. There remain 198 AWOSs.

Automated Surface Observing Systems (ASOS). In a joint program with NOAA NWS, the FAA has procured, installed, and operates ASOS at the remaining airports where the FAA provides observations and at additional non-towered airports without weather reporting capabilities in accord with the levels of service listed above. Production is complete and the FAA has 569 systems installed and will have

all commissioned by the end of CY 2001

Aviation Weather Sensor Systems (AWSS), a new program, will have capability similar to ASOS. However, the AWSS is a direct acquisition of the FAA and not from the joint program. Full production may begin in FY2002, pending funding, with commissioning completed in FY 2003.

The AWOS/ASOS Data Acquisition System (ADAS) functions 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.

The Automated Lightning Detection and Reporting System (ALDARS) is a system adjunct to the ADAS. ALDARS 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 (SAWS) are planned to be back-up for some AWOS/ASOS sensors at locations where no other back-up capability is available. SAWS is in the demonstration phase with full delivery expected in CY 2002.

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 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 (NRVR) 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 take-off 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.

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; deployment will commence in FY 2002.

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 Radar Operations Center (ROC) at Norman, Oklahoma. The ROC provides software maintenance, operational troubleshooting, configuration control, and training. Planned product improvements include a shift to an open architecture, new antenna design, dual polarization, 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.

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 FY 2002.

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 Weather Message Switching Center Replacement (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 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. Two companies have demonstrated preliminary products and capability.

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), NOAA, 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 Forecast and Quality Assurance (AF&QA). The Product Development Team 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. There will be capability to assure quality and a real-time verication process.

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 and the data will be used in new algorithms to develop improved forecasts. The project will continue over a number years as the progress is evaluated. This project is a 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

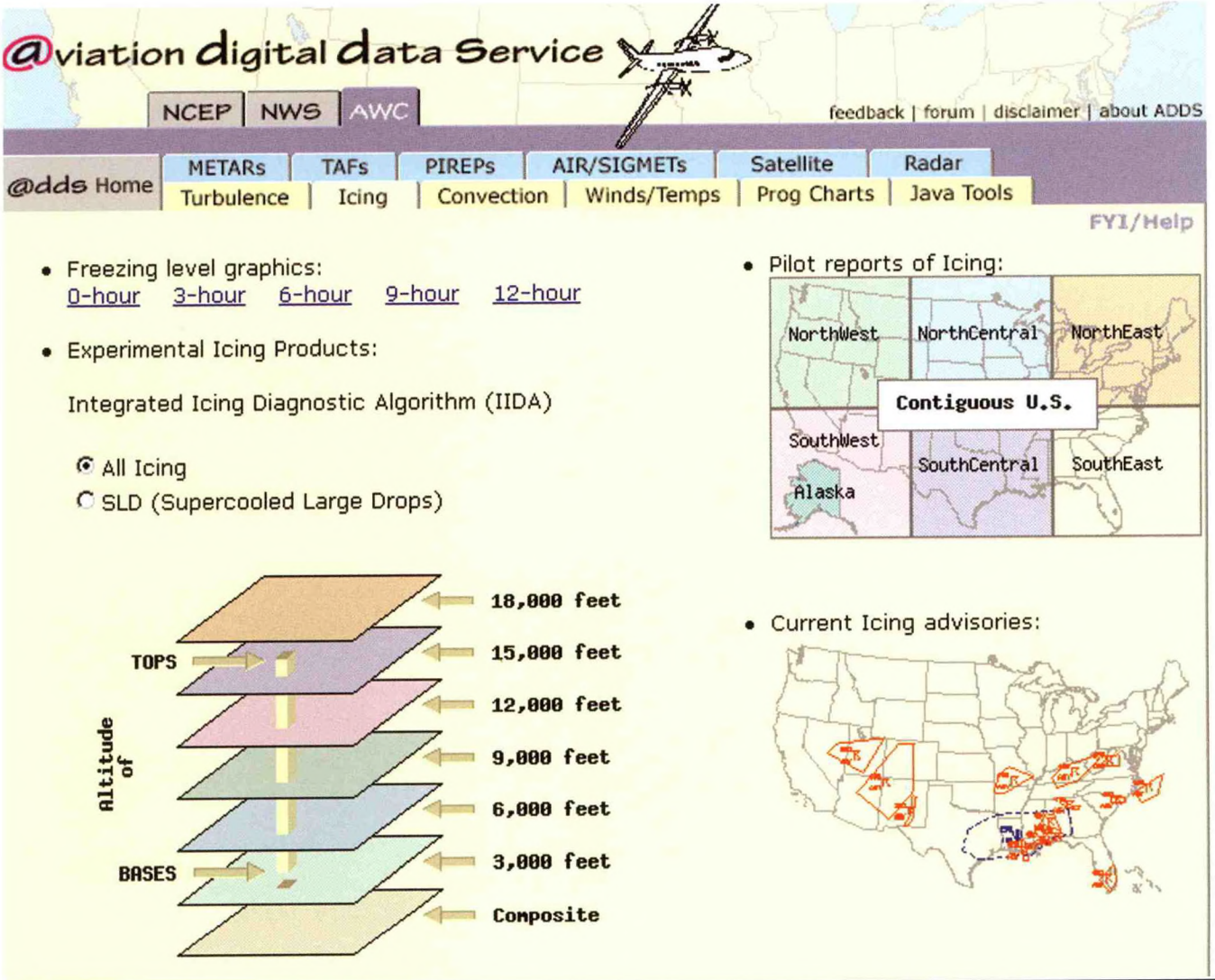
Safer Skies Program, a PDT has a seven year plan to evaluate wind shear and turbulence around and on the approaches to Juneau, Alaska. Also, they are working with certain airlines to install instruments on aircraft with the capability to measure turbulence as sensed on the aircraft and report this information 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.

Space Weather. Space Weather is of concern to the FAA in several areas of operations and regulations. Ionospheric scintillation creates certain errors in the Global Positioning System that affects navigation, especially for instrument approaches to airports. In programs for Wide Area and Local Area Augmentation Systems (WAAS and LAAS) corrections for these effects are being developed. This will be a very important advance to promote the Free Flight management of the National Airspace System. In addition, the effects on the ionosphere have grave impacts on the use of high frequency communications which are essential in air traffic control of flights across the oceans and over the poles of the Earth.

FAA is embarking in research at the Civil Aeromedical Institute in Oklahoma City on the radiation effects on fetuses of newly pregnant women when flying at high altitudes and at high latitudes where exposure is increased. The exposure of flight crews to this hazard will be measured to determine if repeated flights in this regime may accumulate deleterious results.

FAA planners for commercial space operations are working on the weather requirements to set criteria for space launch activities. The commercial launch sites in California, Florida and Virginia are co-located with government sites where the weather support is available. However, at the new commercial space launch site in Kodiak, Alaska new criteria must be developed and established for standard procedures.



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 the 1987 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.

The research program, which was active until 1993, encompassed various technology areas, including Anti-Icing and Roadway Weather Information Systems. The Nation's transportation agencies are currently evaluating and implementing SHRP products. The SHRP Evaluation and Implementation Database (*www.wsdot.wa.gov/fossc/OTA/SHRP/*) contains information on the SHRP Lead States program, SHRP products and vendors, SHRP and other publications, discussion groups, a personnel directory, and a calendar of SHRP-related events. A new research program is being developed to address transportation issues likely to be of concern in the next 20 years.

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 Architecture, 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. A new user service is being added to the National ITS Architecture that focuses on Maintenance and Construction Operations (MCO), including roadway maintenance and maintenance vehicle fleet management.

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 weather information applications for winter maintenance managers, traffic managers, and emergency managers. RWIS initially referred only to the fixed roadside sensor suites for pavement condition (temperature, chemical concentration, surface water/snow/ice), surface weather observations (temperature, relative humidity, winds, visibility, precipitation), and air/water quality conditions. Figure 3-DOT-4 reflects the widespread deployment of Environmental Sensor Stations (ESS) throughout the United States. Over time, the RWIS definition has broadened to include sensor systems, communication systems, and central analy-

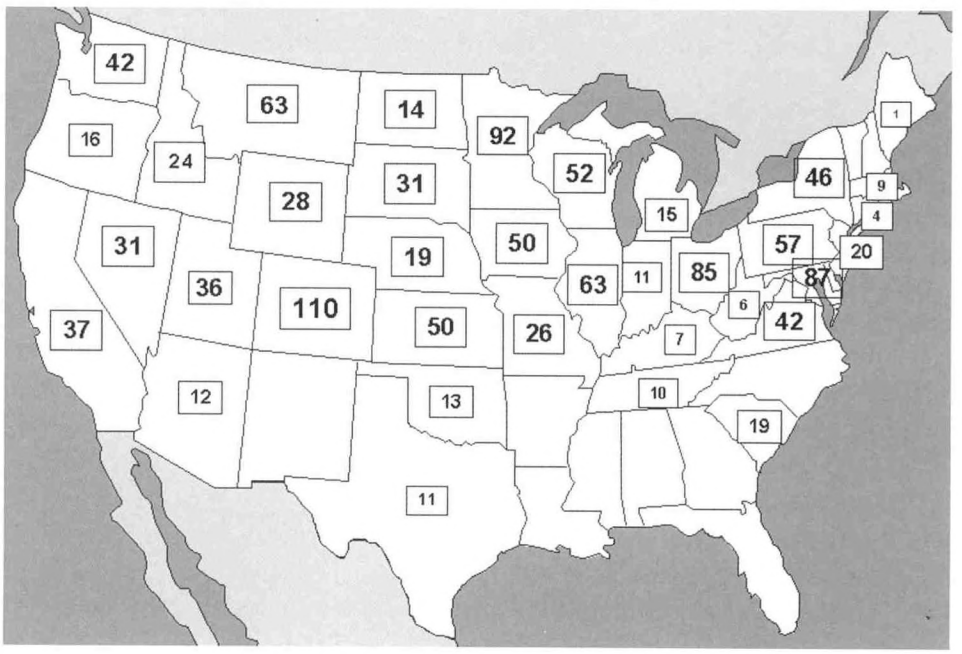


Figure 3-DOT-4. Pavement and ESS Technology Deployment.

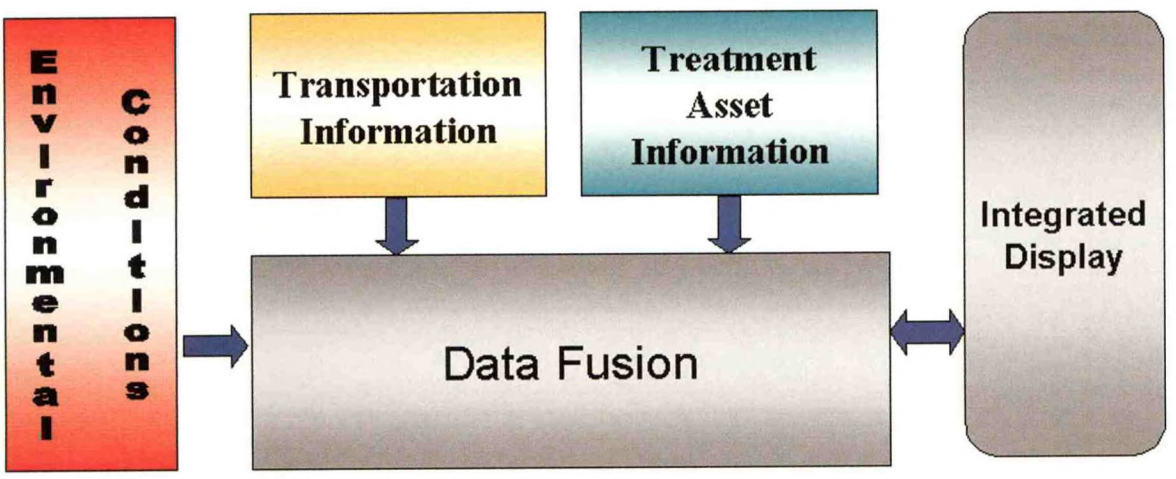
Maintenance Decision Support System (MDSS) Project For the FHWA Road Weather Management Program

The Maintenance Decision Support System (MDSS) project is a multi-year effort to prototype and field test advanced decision support components for winter road maintenance managers. The development of a prototype MDSS is part of the Surface Transportation Weather Decision Support Requirements (STWDSR) initiative conducted by Mitretek Systems, Inc. The documents STWDSR V2.0[1] and the MDSS Project Plan[2] give background information on the project and operational concept for decision support associated with winter road maintenance. These documents explain the process used by the FHWA and stakeholder groups (users, vendors, and researchers) to produce the MDSS prototype.

The MDSS is based on leading diagnostic and prognostic weather research capabilities (high resolution numerical forecast models and experimental algorithms) and road behavior (surface and subsurface), which are being developed at six national research centers. It is anticipated that components of the prototype MDSS system developed by this project will ultimately be deployed by road operating agencies, including state departments of transportation (DOTs), and generally supplied by private vendors.

The MDSS project goal is to develop a prototype capability that: (1) capitalizes on existing road and weather data sources, (2) augments data sources where they are weak or where improved accuracy could significantly improve decision-making tasks, (3) fuses data to create an open, integrated and understandable presentation of current environmental and road conditions, (4) processes data to generate diagnostic and prognostic maps of road conditions along road corridors, with emphasis on the one- to 48-hour horizon (historical information from the previous 48 hours will also be available), (5) provides a display capability on the state of the roadway, and (6) provides a decision support tool that includes recommendations on road maintenance courses of action. All of the above will be provided on a single platform, with simple and intuitive operating requirements in a readily comprehensible display of results and recommended courses of action, together with anticipated consequences of action or inaction.

With user needs in mind, a conceptual structure of the prototype MDSS has been developed. The prototype MDSS is divided into five primary elements as shown in the diagram below.



[1] STWDSR V2.0 Operational Concept Description (*http://www.itsdocs.fhwa.dot.gov/jpodocs/EDLBrow/401!.pdf*) and Preliminary Interface Requirements (*http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@701!.pdf*)

[2] MDSS Project Plan (*http://www.ops.fhwa.dot.gov/weather/mdss.pdf*)

sis systems providing weather information used to improve roadway maintenance and traffic operations, as well as ensure public safety. Consequently, the more precise term for the sensors, both fixed and mobile, is the ESS. The ESS Standard defines protocols for data passage from a roadside sensor or maintenance vehicle to a central processing unit. This observing network is sparse, with about 1,200 remote units covering four million highway route miles. Techniques such as thermal mapping or use of heat value models with ESS data are necessary to extend coverage of road condition information.

Winter maintenance managers have found anti-icing--the pretreatment of roads for better snow removal and ice control--to be cost-effective. Anti-icing relies heavily on RWIS as well as weather and pavement condition products specifically aimed at the highway maintenance community. Traffic managers are able to better manage surface transportation infrastructure and provide information to travelers with RWIS data. For example, traffic signal start-up times may be lengthened under icy pavement conditions or speed limits may be lowered under low visibility conditions. Emergency managers may use RWIS data to make evacuation decisions under hurricane threats.

Advanced Transportation Weather Information System (ATWIS)

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

FORETELL

With the intent of integrating RWIS with other ITS services, the FORETELL project was initiated with 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.

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 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. Accidents, road closures, congestion, weather conditions, delays, lane closures, current weather conditions are among the many types of information displayed on the website.

With FORETELL, highway operating agencies will be able to detect changing conditions sooner and provide advanced warnings and information to the public. Due to increased levels of forecast detail, highway and maintenance professionals will be able to make more informed decisions about the roadway network and more effectively manage resources while maintaining high levels of service. The public will be able to make more specific travel decisions, based on highly detailed road weather information. Additionally, public-public and public-private partnerships will result in improved coordination between FORETELL partners, affiliates and their RWIS and related ITS deployments.

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-5 reflects these regional road weather information systems across the United States ranging from the I-95 Corridor Information Exchange Network (IEN) project to *rWeather* 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?

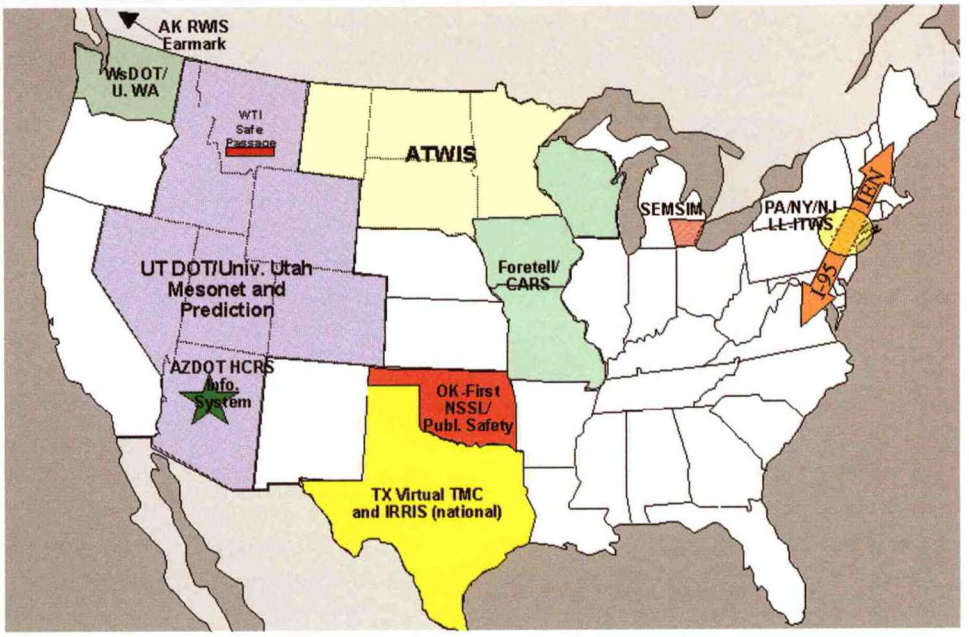


Figure 3-DOT-5 . Regional Weather Information systems.

Current Benefits

The cost savings for a state's highway winter maintenance operations have been achieved due to 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 system 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.

Improved winter maintenance practices that reduce chemical and abrasive usage also minimize environmental impacts. Dissemination of road weather information to drivers can enhance safety and improve mobility. A Nevada DOT RWIS provides warnings to truck drivers on US 395 when wind gust exceed 30 mph, significantly reducing high-profile vehicle accidents. The Adverse Visibility Information System on Interstate 215 in Utah automatically displays recommended travel speeds based upon prevailing visibility and traffic conditions. In response to advisory messages, overly cautious drivers increase speed causing a 22 percent reduction in speed variation resulting in more uniform traffic flow and reduced accident risk.

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 how traffic and incident managers can optimize the performance of their system.
- In coordination with current federal programs, such as Professional Capacity Building and Local Technology Assistance Programs, 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 FORETELL field operational test.

The Maintenance Decision Support System (MDSS) project is a multi-year effort to prototype and field test advanced decision support components for winter road maintenance. The prototype development phase is being conducted by a team of six national research laboratories with expertise to winter road maintenance decision support. This effort will lead to an operational test of the MDSS, as well as produce decision support components that private vendors can incorporate into their products for maintenance managers.

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 DOTs, 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 ESS siting, 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 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.

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 DOTs, 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 development organizations, and national committees and associations dealing with surface transportation weather and winter mobility. To date there have been some 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.

The Federal Railroad Administration (FRA) supports improving the collection, dissemination, and application of weather data to enhance railroad safety through the Intelligent Weather Systems project, as part of the Intelligent Railroad Systems and Railroad System Safety research programs. These programs address safety issues for freight, commuter, intercity passenger, and high-speed passenger railroads.

Intelligent Weather Systems for railroad operations consist of networks of local weather sensors and instrumentation - both wayside and on-board locomotives - combined with national, regional, and local forecast data to alert train control centers, train crews, and maintenance crews of actual or potential hazardous weather conditions. Intelligent weather systems will provide advance warning of weather-caused hazards such as flooding; track washouts; snow, mud, or rock slides; high winds; fog; high track-buckling risk; or other conditions which require adjustment to train operations or action by maintenance personnel (Figure 3-DOT-6). Weather data collected on the railroad could also be forwarded to weather forecasting centers to augment their other data sources. The installation of the digital data link communications network is a prerequisite for this activity.

Figure 3-DOT-6. Track trussel washed out by flood waters.

FRA intends to examine ways that weather data can be collected on railroads and moved to forecasters, and ways that forecasts and current weather information can be moved to railroad control centers and train and maintenance crews to avoid potential accident situations. This research is estimated to continue for 5-6 years after it begins. This is one of the partnership initiatives identified in the NSTC's *National Transportation Technology Plan*.

The Federal Transit Administration's (FTA) mission is to "*provide leadership, technical assistance and financial resources for safe, technologically advanced public transportation which enhances all citizens' mobility and accessibility, improves America's communities and natural environment, and strengthens the national economy.*" In this context, FTA provides an energy efficient means of transporting people, thereby, reducing emissions caused by transportation and lessening the Nation's dependence on fossil fuels, including foreign oil. One-hundred gallons of fuel can be saved each year for every person riding the bus instead of driving. The savings by train and trolley riders are even greater.

The United States Department of Transportation (DOT) has a variety of research development and demonstration programs and initiatives that are targeted at reducing the emissions and improving the efficiency of vehicles including trucks, buses, marine vessels, airport support equipment, and other specialty vehicles. The underlying assumption of many of these public-private partnership efforts is to improve current vehicles without sacrificing vehicle performance or limiting consumer choices in the marketplace.

Figure 3-DOT-7. Protoype of FTA's electric bus program.

In particular, the FTA Fuel Cell Transit Bus Program and the Hybrid Electric and Electric Bus Program (Figure 3-DOT-7) focus on developing and demonstrating innovative transit bus technologies that can improve the energy efficiency and reduce harmful emissions from transit buses, including greenhouse gas emissions. Through these efforts, the benefits and viability of both fuel cells and hybrid electric drive technology for transit bus applications are being demonstrated.

Similarly, the Advanced Vehicle Technologies program (AVP) managed by DOT, is a collaborative program between the Federal government and over 500 companies, universities, national laboratories, state, regional, and local governments focused on innovative technologies for medium and heavy-duty vehicles that can lessen the transportation sector's dependence on foreign oil, reduce emissions from transportation vehicles, and enhance the development of a domestic advanced transportation industry. The technologies developed and demonstrated under the program are closely related to transit research needs, or directly develop and demon sate advanced technologies for transit.

The Transit Cooperative Research Program is currently researching FTA's role in avoiding greenhouse gas emissions. Project H-21 is examining how transit service can contribute to community sustainability and provide enhanced mobility while addressing climate change at the community and regional level.

One example of research for vehicle emissions is with the Desert Research Institute (DRI) to develop and test a new remote sensing device that accurately estimates particulate emissions from motor vehicles and will quantify the contributions of ozone precursor and small particular emissions from sources outside the Las Vegas metropolitan area. The meteorological and air quality modeling will attempt to quantify the level of emissions transported into the area from the Los Angeles South Coast Air Basin.

In FTA's national rural and parks programs coordinated with the research efforts currently underway with the Weather Information for Surface Transportation (WIST) initiative. This research will take advantage of other related rural ITS weather resources to integrate transit and emergency services through the "Common Communication Backbone Concept." Many rural areas can greatly benefit

Figure 3-DOT-8. Weather poses a significant impact on transit operations in the Washington metropolitan area. (WMATA Photograph)

from a Joint Operational center that consolidates transit management, emergency management, and emergency medical service operations utilizing light rail, ferry, van, and bus transit services. This integrated management and transit emergency service will enable rural transit operators to manage weather-related incidents more efficiently, while improving the coordination with travelers and emergency management staffs (Figure 3-DOT-8.).

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 conducted successful shakedown tests of the hull, machinery, and scientific equipment during January-August 2000 (Figure 3-DOT-9). The first unrestricted science cruise is scheduled for the Eastern Arctic in the summer of 2001. HEALY, has a length of 420 feet, beam of 82 feet, and displaces

Figure 3-DOT-9. USCGC HEALEY, the Coast Guard's new icebreaking research vessel, conducting ice trials.

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/*.

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. Five Coast Guard personnel fill key technical and logistics support positions within NDBC. 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 continued expansion in export markets has reduced stocks and benefitted our farm sectors as global consumption of total grains has exceeded production in recent 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 (Figure 3-USDA-1). 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. A weather information management system and a library to archive all FS weather data are being developed in cooperation with regional climate centers. The FS monitoring network will provide essential data for use in Global Change Research Program (GCRP) work.

The FS 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

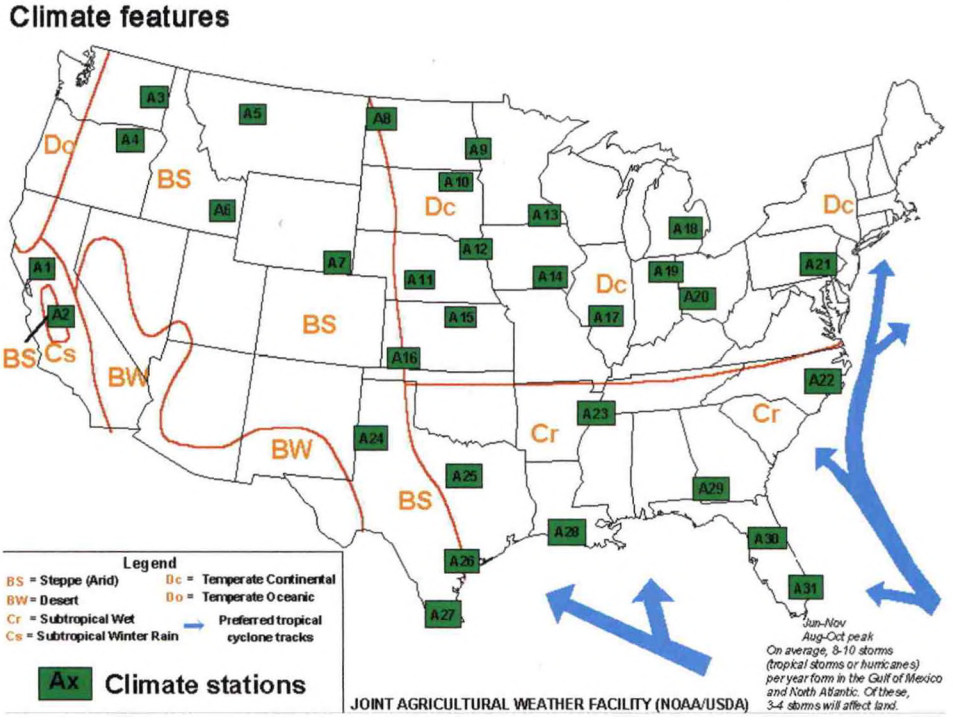


Figure 3-USDA-1. United States Climate and Crop Information depiction of climate features. [Source: Joint Agricultural Weather Facilty (JAWF) web site.]

Geostationary Operational Environmental Satellite (GOES) telemetry. These data are received via a direct-readout ground site in Boise, Idaho, in cooperation with the Bureau of Land Management. The main use of the data is in the calculation of the fire danger rating for the FS and cooperating agencies. These data are also used by other resource managers, such as, road engineers, wildlife biologists, and hydrologists who monitor precipitation; silviculturalists (who are attempting to maximize tree-planting opportunities); and ecologists, soil specialists, and fisheries biologists (who monitor the effects of runoff). Another major user of RAWS data is the NWS for fire weather forecasting and flood warnings.

The Natural Resources Conservation Service (NRCS) continues to operate 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.

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.

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. 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 Extension 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 almost 60 years, the Department of Energy (DOE) and its predecessors, the Atomic Energy Commission (AEC) and the Energy Research and Development Administration (ERDA), 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, starting in the late-1960's, by the passage of environmental protection legislation under 40 CFR, 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. Quality-assured meteorological data is an important element of a DOE Integrated Safety Management System (ISMS) since it supports the development of Authorization Basis (AB) safety documentation, the consequence assessments of an emergency management system, and the preparation of environmental compliance activities.

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 processes of the atmospheric domain in order to enhance predictive capabilities, particularly to understand how various atmospheric energy-related phenomena interacts with the ocean and terrestrial systems. 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 the Office of Science (SC), Defense Programs (DP), Environmental Management (EM), and Energy Efficiency and Renewables (EE). At its core, DOE is a science agency. DOE is the third largest government sponsor of basic research, following the National Institutes of Health and the National Science Foundation. DOE has principal responsibility for basic research in high-energy physics, nuclear physics, and fusion energy sciences. DOE also supports important research in the material science, biology, chemistry, nuclear medicine, global climate change research, and computational science. The Office of Science underpins the applied research and development conducted throughout DOE. The Office of Biological and Environmental Research (BER) has been a member of the Office of the Federal Coordinator for Meteorology (OFCM) since the early eighties, and it is with this tradition that BER participates and supports the various DOE-mission-related activities of the OFCM.

Over the years, there has been some examples of technology transfer from research to operations, such as some of the science associated with DOE's Atmospheric Studies in Complex Terrain (ASCOT) program, contributing to the various modeling routines in the Atmospheric Release Advisory Capability (ARAC) national emergency response service, that is used as an emergency response tool at the DOE field sites and other locations.

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, atmospheric chemistry, 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 have the potential to impact site operations, damage property, or threaten lives. DOE-wide lightning safety initiatives, which are becoming integral elements of a ISMS, are supported by DOE operational meteorological programs.

Several DOE field offices and their associated sites and facilities cover large areas (e.g., Idaho National Engineering and Environmental Laboratory (INEEL) nearby Idaho Falls, Idaho; Oak Ridge Reservation in Oak Ridge, Tennessee; Nevada Test Site nearby Las Vegas, Nevada; Hanford nearby Richland, Washington; and Savannah River Site, nearby Aiken, South Carolina). In addition, several DOE sites are situated in areas of complex topography and heterogeneous surface characteristics, creating mesoscale conditions that locally influ-

ence onsite weather and atmospheric transport and diffusion. For these reasons, and to protect public health and safety and environment, onsite meteorological monitoring programs have been, remain, and will always be 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 NWS and community 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). Some DOE sites employ the National Oceanic and Atmospheric Administration (NOAA) Advanced Weather Information Processing System (AWIPS) [e.g., NOAA Air Resources Laboratory (ARL)/Special Operations and Research Division (SORD), Las Vegas, Nevada].

An accidental release of radioactive, chemical, or even biological toxic material into the atmosphere can have potentially serious health effects, as well as environmental consequences. Meteorological transport and dispersion processes play a key role in determining the fate of radioactive, toxic chemical, or biological agents 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 accurately measuring and characterizing the important atmospheric processes.

In recognition of this need, DOE has established and supported onsite 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 onsite work force and the public. In addition, research on the modeling of the transport, dispersion, deposition, and resuspension of radioactive, toxic chemical, and biological agent materials is undertaken to refine the models used in these endeavors. Onsite weather forecasting services, each tailored specifically for the special operational and emergency management requirements at each DOE site, provide necessary support to the safety and health programs designed to protect 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 fifteen (15) separate DOE sites:

Argonne National Laboratory (ANL)

Argonne National Laboratory (ANL) is one of DOE's largest research centers. It is also the nation's first national laboratory, chartered in 1946. The University of Chicago manages and operates Argonne for the DOE Chicago Operations Office. Argonne occupies two sites, designated as ANL-East in Illinois and ANL-West in Idaho. The Illinois site is surrounded by forest preserve on 1,500 wooded acres about 25 miles southwest of Chicago's Loop. The site also houses the DOE Chicago Operations Office. Argonne-West occupies about 900 acres about 50 miles west of Idaho Falls in the Snake River Valley. It is the home of most of ANL's major nuclear reactor research facilities.

There are three divisions, Environmental Research (ER), Decision and Information Sciences (DIS) and Environmental Assessment (EAD) at ANL with meteorological research or operational program support. Two cross-divisional groups are involved in these programs at ANL: the Atmospheric Research Section (ARS) and the Atmospheric-Emergency Preparedness (AEP) Group. The ARS is composed of scientist with research activities in both basic and applied science; particular technical strengths are in the areas of air-surface exchange, remote sensing, atmospheric chemistry, and numerical modeling. About half of the ARS support is currently devoted to activities associated with the DOE Atmospheric Radiation Measurement (ARM) Program. The AEP is composed of scientists and engineers in two divisions involved in programs with a greater emphasis on applied science. Particular technical strengths include air pollution meteorology, emergency preparedness and response, and stochastic systems simulations. More than half of the AEP support is associated with DOE's PROTECT Critical Infrastructure Program involving chemical and biological agents.

ARS has operated and maintains a 60 meter (m) meteorological tower and supplies meteorological data for emergency response, facility operations, and regulatory compliance for ANL

operations. Wind and temperature measurements are taken at the 10m and 60m levels. Real-time and historical data are available via the Web (*http://gonzalo.er.anl.gov/ANLMET*).

As part of a larger program for the protection of subway systems from terrorist attacks using chemical agents, AEP is installing sonic anemometers as well as temperature and pressure sensors in the subway tunnels of a large urban subway system. These instruments will assist in the understanding of flows in the tunnels, which are driven by a combination of: (1) the "piston" action of train motion and (2) buoyancy effects and above ground forcing. Measurements from these instruments will be correlated with the above ground measurements to develop and validate predictive and emergency response models for flow and dispersion in subway systems. The AEP group research also focuses on the analysis of routinely measured meteorological data to provide atmospheric boundary layer turbulence information for atmospheric dispersion calculations. Under the Department of the Army Chemical Stockpile Emergency Preparedness Program (CSEPP), ANL provides support to improve the collection efficiency and quality of meteorological data measured at the Army's Demilitarization towers. The data are used the emergency operation centers in support of emergency response exercises and for use in real-time in the event an actual accident. The goal of the CSEPP support is to improve the accuracy and robustness of the data obtained from the meteorological monitoring stations and to develop unified quality control and analyses procedures of the data collected by the towers.

Key support is also provided to Department of Transportation (DOT) in applying an ANL-developed 5-year meteorological database for over 100 locations in the United States to conduct statistical analyses of hazardous materials incidents on a national basis. Recent work for DOT has centered on development of the Table of Initial Isolation and Protective Action Distances for the 2000 Emergency Response Guidebook. Protective Action Distances are given in the Table for over 200 toxic-by-inhalation chemicals and generic compounds for both daytime and nighttime accidents, and represent the safe distance for 90 percent of hazardous materials transportation accidents considering variability in meteorology and spill size. Recent work for DOT has also involved conducting national risk assessments for transportation of certain high volume toxic chemicals like chlorine, ammonia, hydrogen fluoride and sulfur dioxide.

The Atmospheric Boundary Layer Experiments (ABLE) is one of several DOE supported research programs conducted by the ARS. ABLE is located on the lower Walnut Watershed, mostly in Butler County east of the city of Wichita, Kansas. This location is within the existing boundaries of the DOE Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) Clouds and Radiation Test bed (CART) site. The establishment of this facility offers a virtual atmospheric observatory and provides essential research tools for addressing a myriad of unresolved fundamental questions in atmospheric research. The ABLE provides a continuous view of processes in the lower atmosphere over a limited domain within the SGP CART site.

ABLE Doppler Minisodar

General Purpose: The minisodar measures wind profiles from about 10m to 200m above the surface, thus filling in the gap left below the minimum height of the wind profilers. Primary Quantities Measured: The primary quantities measured the the system are the intensity and Doppler shift of backscattered acoustic energy from index of refraction fluctuations (created by temperature and wind fluctuations) embedded in the atmosphere. Description: The minisodar has been developed and fabricated at Argonne National Laboratory (ANL). It consists of a 32 element array of piezoceramic tweeters mounted vertically within a protective enclosure roughly 1.5 m X 1.5m X 1.5m. The acoustic "in phase" transmission is reflected off a plate into a vertically propagating wave. This orientation enables the system to operate in all weather conditions. The minisodars operate by transmitting in two different vertical planes and receiving backscattered energy from refractive index fluctuations moving with the mean wind. By sampling in the vertical direction and two tilted planes, the three components of motion can be determined. The system consists of a single phased array antenna that transmits alternately along three pointing directions: one vertical, one in the north-south vertical plane (to the north) and one in the east-west vertical plane (to the east). The non-vertical beams are tilted about 17 degrees from vertical. Radial components of motion above each pointing direction are determined sequentially, separated by about 1.5 seconds. Thus, the system repeats its sequence about every 5 seconds. The data from each transmit pulse are processed with a FFT centered about each range gate (e.g. every 5m increment in the vertical) to determine the mean Doppler shift. The signal-to-noise ratio is used to determine if each estimate is acceptable. All the acceptable data within an averaging interval (e.g. 15 minutes) are averaged and combined to produce a wind profile if there are enough acceptable data points (25 percent, e.g.) within the interval. The averaged data are output in files with format similar to radar wind profiler (".sod") format for consistency. High resolution radial moments data and spectra can be produced if desired.

The initial focus of the ABLE is measurements of the planetary boundary layer (PBL) where almost all interactions between the atmosphere and humans take place. Many scientific issues may be addressed by use of such a facility, including:

- Natural disaster reduction and public safety;
- Safe and efficient aviation and other transportation;
- Agriculture;
- Water resource management;
- Effective energy production, use and environmental protection;
- Space flight operations;
- Defense; and,
- Related areas of Earth Science.

Instrumentation at the ABLE site includes winds, temperatures, moisture, surface net radiation and soil moisture as the minimum set of atmospheric observations.

The initial set of equipment, which is be available at the ABLE includes:

- Three 915 MHz RWP-RASS (wind speed and direction, virtual temperature profiles);
- Three minisodars (wind and turbulence profiles between heights of 10m and 200m);
- One lidar ceilometer (cloud base height);
- One balloon-borne sounding system (wind, temperature, moisture profiles);
- Five surface flux stations (surface sensible and latent heat, ground heat storage);
- Five soil moisture sampling stations (soil moisture and soil temperature);
- One satellite data receiver-processor;
- One data hub/central location for data collection; and,
- One (extra) instrument pad for visiting scientist instrument accommodation.

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 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 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:

- Instrumentation development for field studies of atmospheric constituents, air-sea interaction, and laboratory experiments;
- Gaseous tracer studies of atmospheric transport and dispersion;
- Aerosol formation and behavior;
- Atmospheric pollution studies;
- Modeling of atmospheric chemical reactions;
- Acid rain studies both in the field and in the laboratory;

Figure 3-DOE-1. Battelle operates the Gulfstream-1 as a research facility under contract with the DOE's Atmospheric Chemistry Program.

- Theoretical and observational studies of radiative transfer and fluxes; and,
- 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 (Figure 3-DOE-1). The ARM External Data Center is the center for collection, archival, and dissemination of all climate-related data sets for the ARM program.

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 National Aeronautics and Space Administration (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 2-3 km 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.

Hanford

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:

- Southern Great Plains of Oklahoma;
- Tropical Western Pacific just off northern part of Papua, New Guinea; and,
- North slope of Barrow, 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:

- Extensive data acquisition via a site-wide meteorological monitoring network;
- Weather forecasting services 24-hours/day (Monday through Friday), and 8-hours/day on weekends and holidays;

- Hourly surface observations, and 6-hourly synoptic observations; and,
- Monthly and annual climatological data summaries, plus meteorological input to annual environmental reports.

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 15m tall and provide wind speed and direction at 15m and air temperature at 2 and 15m (Figure 3-DOE-2). Fifteen of the 15m towers also provide relative humidity

Figure 3-DOE-2. Meteorological towers record temperature and wind direction and speed at various levels.

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 additional 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)

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 at *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:

- Understanding the transport, diffusion, deposition, transformation, and atmospheric effects of accidental releases or pollutants;
- Developing and testing models for improved representation of atmospheric processes on building, urban, regional, and global scales;
- 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;
- Understanding the role of pollutants from fossil fuel emissions in determining greenhouse gas and aerosol concentrations and climate forcing;
- Understanding and predicting the extent to which stratospheric ozone may decrease as a result of anthropogenic emissions;
- Understanding and quantifying the natural variability of the climate system; and,
- 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--Program for Climate Model Diagnosis and Intercomparison (PCMDI) and National Atmospheric Release Advisory Center (NARAC). 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 NARAC program. NARAC 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 NARAC 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. NARAC supports all elements of the DOE Emergency Preparedness and Response Program, NEST, ARG, FRMAC, and the Radiological Assistance Program (RAP).

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 NARAC 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 NARAC responses is located at *http://air.llnl.gov/*.

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, infrasound 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 infrasound 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:

- Radiation budget and cloud forcing;
- Water and energy budgets; and,
- 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.

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 lakebeds 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 twenty-nine (29) 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 AWIPS, or from University Center for Atmospheric Research (UCAR) and ARL-Silver Spring. Weather products are 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 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.

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 the University of Tennessee/Battelle, BWXT Y-12 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 supplemental towers are still operating. Lastly, 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 (i.e., 100m and 60m) located at the east and west ends of the site, respectively, and a Remtech Sodar reporting vertical profile data from 50-500m. 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.

Pantex Plant

The Pantex Plant covers 15,977 acres and is located 27 kilometers (km) (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 has been the operating contractor since 1956. On February 1, 2001, BWXT Pantex has assumed the Pantex contract.

The Plant is composed of several functional areas, commonly referred to as numbered zones. These include a weapons assembly/disassembly area, a weapons staging area, an area for development of experimental explosives, a drinking water treatment facility, a sanitary wastewater treatment facility, and vehicle maintenance and administrative areas. Other functional areas include a utility area for steam and compressed air, an explosive test-firing facility, a burning ground for thermally treating explosive materials, and landfills. Overall, there are more than 700 buildings at the Pantex Plant.

The Environmental Protection/ Restoration Department (EP/RD) of the Environment, Safety and Health Directorate 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 NARAC site workstation, 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 NARAC emergency response models that could be used for off-normal events involving radionuclides. Annual dispersion model calculations of offsite radiation doses from on site sources, required by 40 CFR 61, Subpart H, *National Emission Standards for Hazardous Air Pollutants* (NESHAP), are accomplished by the EP/RD. EP/RD uses the EPA-approved CAP88-PC model and the Pantex meteorological tower data processed into the STAR format. This department 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 the Pantex Emergency Management Department. 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 meteorological 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.

As a result of a FY 2000 project meteorological tower data is now displayed on the Pantex Plant Intranet for use by Plant personnel. During FY2001, the potential for replacing the existing wind sensor on the meteorological tower with a 3-dimensional wind sensor will be evaluated. In addition, replacing/upgrading the NARAC computer and software located at the base of the tower that feeds data into the NARAC Site System in the EOC will also be considered.

There are no current or projected supporting meteorological research activities planned at the Pantex Plant.

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. The data are analyzed, quality assured, and assembled into data sets for use in atmospheric modeling, cli-

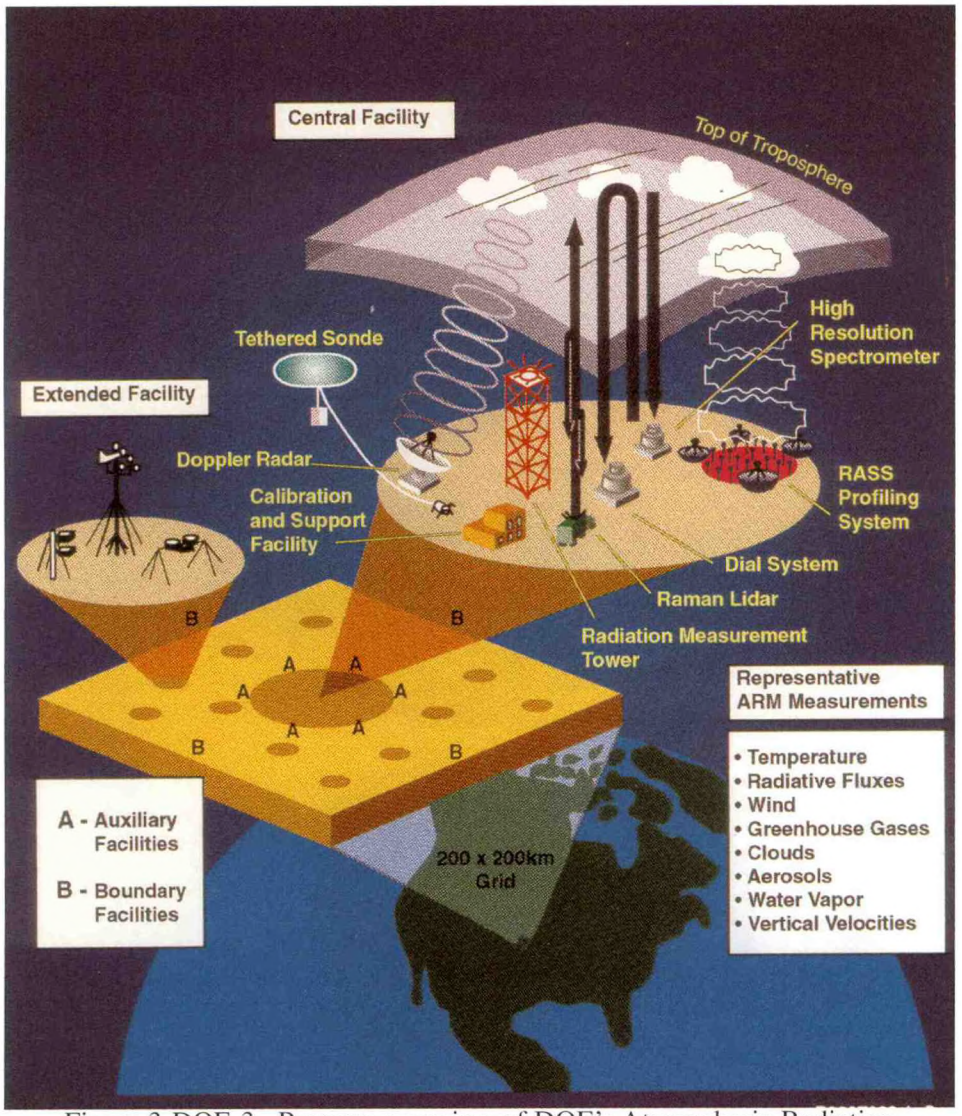


Figure 3-DOE-3. Program overview of DOE's Atmospheric Radiation Measurement (ARM) Program.

matology, 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.

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 mountain-

ous 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:

- Emergency response;
- Environmental surveillance and characterization; and,
- 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 the Arctic Ocean (SHEBA). The ARM project is a combined measurement and modeling program (Figure 3-DOE-3). 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.

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 nonproliferation 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 (Figure 3-DOT-4).

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

Figure 3-DOE-4. Tethered meteorological Tower (Tethersonde).

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 (20km 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.

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 10m 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 DOE Oak Ridge Operations Office (ORO), and operated by an integrated Project Management Contractor (PMC) consisting of MK-Ferguson and Jacobs Engineering Group, Inc. WSSRAP, which is approximately 30 miles west of St. Louis, Missouri, is approaching completion.

The mission of the WSSRAP has been to conduct environmental restoration of the following:

- A 166-acre inactive uranium feed materials plant (i.e., chemical plant area);
- A 51-acre raffinate pit area;
- A 9-acre limestone quarry located 4 miles from the main site; and,
- Associated vicinity properties.

Within the scope of remediation is cleanup of both radiological and chemical contaminants resulting from historical operations that included trinitrotoluene (TNT) and dinitrotoluene (DNT) production (i.e., 1941-1945), and uranium processing (i.e., 1956-1966).

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, polychlori-

nated 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.

A meteorological monitoring program has been operated at the WSSRAP since 1994. The program consists of a single monitoring station, located at the eastern edge of the chemical area, more than 400 ft from the nearest building and is considered representative of all areas undergoing remediation. The WSSRAP meteorological station continuously measures and records wind speed and wind direction at 10m above ground level, as well as horizontal wind fluctuation at 10m above ground level, barometric pressure, relative humidity, solar radiation, and precipitation intensity.

The data collected by this station has been used to support numerous project functions at the site, including:

- Meteorological information to support emergency response activities in the event of an unscheduled chemical or radiological release;
- Information for atmospheric dispersion modeling to provide an environmental safety and health contribution to engineering design of site facilities;
- Rainfall, temperature, and wind speed data to support wetland and lake ecological studies and for support of foliar vegetation absorption analysis;
- Precipitation data to support the correlation of aquifer level fluctuations in the quarry and Femme Osage Slough;
- Environmental reporting including the annual Site Environmental Report and the Effluent Information System/On-Site Discharge Information System Report;
- Wind speed data needed for compliance with Occupational Safety and Health Administration (OSHA) construction management activities;
- Precipitation data to support the National Pollutant Discharge Elimination System (NPDES) storm water permit application;
- Temperature and relative humidity data to support environmental safety and health field activities during periods of extreme heat and cold;
- Groundwater studies to evaluate the impact of rainfall on contamination in the underlying aquifer; and,
- Wetland and lake ecological studies for support of foliar vegetation absorption analysis.

As of the end of 2000, the site has been essentially remediated and almost all contaminated materials have been permanently disposed in the 45-acre onsite disposal cell. The contaminated material in the cell is covered by at least I foot of clean soil, and the cell cap is due to be placed during 2001. Thus, the meteorological station is no longer necessary to support radiological activities or dispersion modeling. However, it will continue to be operated for at least another year in support of general construction activities and groundwater studies.

Yucca Mountain Project (YMP)

As part of DOE's Office of Civilian Radioactive Waste Management (OCRWM), the Yucca Mountain Project (YMP) studies may eventually support a recommendation of Yucca Mountain for the nation's first geologic repository for spent nuclear fuel and other high level radioactive waste. The current meteorological program within the YMP focuses on environmental compliance and operational health and safety considerations, for both employees and the general public (Figure 3-DOE-5).

As with a number of DOE sites, the Yucca Mountain area is one of complex topography and heterogeneous surface characteristics, creating mesoscale conditions that locally influence onsite weather. The YMP meteorological program, therefore, includes four full stations for measuring atmospheric dispersion and general meteorological conditions, as well as nine precipitation stations. These stations serve to monitor the significant variations in airflow, rainfall, and temperature caused by the area's complex terrain environment. The meteorological stations are key to the thorough monitoring of these variations that is essential for YMP's ongoing commitment to

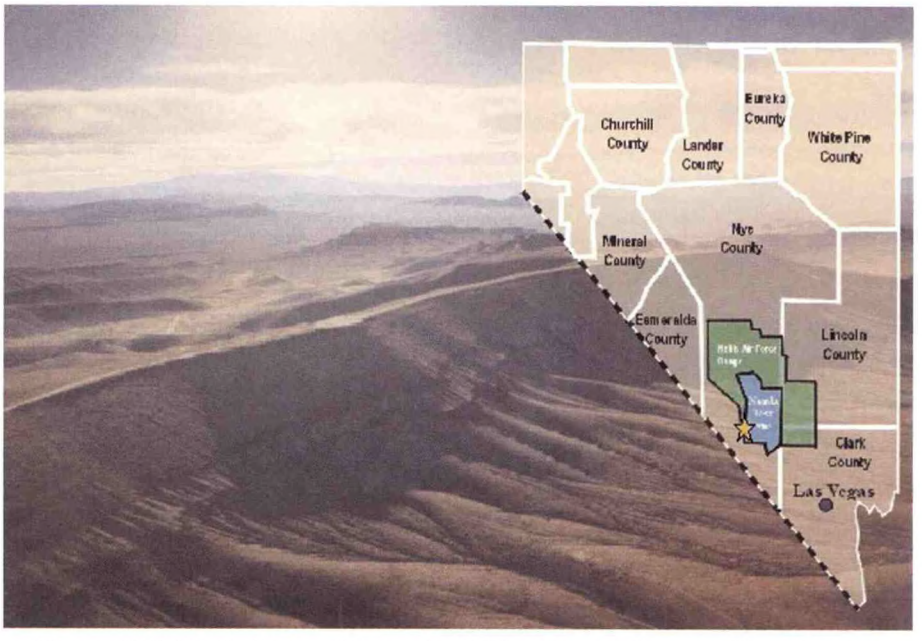


Figure 3-DOE-5. Yucca Mountain (100 miles northwest of Las Vegas, Nevada) is unpopulated land owned by the Federal Government and adjacent to the Nation's nuclear weapons test site.

environmental compliance and to the health and safety of employees and the public.

The YMP meteorological program also provides essential data for the studies necessary to evaluate the site's suitability for a potential repository. Should the site be deemed suitable and a repository licensed, built, and operated, water would be the primary means by which radioactive materials could be transported to the accessible environment. Thus, movement of water from the atmosphere to the surface and on through the mountain is a key concern. The meteorological program provides essential data for the infiltration model of the mountain. Data about precipitation, humidity, evapotranspiration, surface water run-on, solar radiation, air temperatures, and wind patterns all contribute to the overall infiltration model. The model gives special emphasis to the transient, or temporal, versus steady-state rates of water movement through the unsaturated zone of rock at Yucca Mountain. The temporal variation of infiltration may be short term, due to weather fluctuations that drive episodic flow, or much longer term, in periods corresponding to climate change. Data from the meteorological program's ongoing monitoring programs are supplemented by the program's paleoclimatology studies. Together, they provide essential information for the YMP modeling of past, present, and future infiltration rates.

If the potential repository were actually built and operated, continuous meteorological monitoring and analysis would also be essential for the operational facilities on the surface of the mountain, at least until the final closure of the repository. Buildings would be built to withstand the probable maximum flood and wind conditions, and administrative controls would be in place to suspend operations during severe weather conditions. An integral part of the emergency response system would include monitoring the overall environmental situation at the repository site. In turn, an integral part of the overall environmental monitoring system would be the meteorological monitoring system. This system would collect real-time meteorological information about the site and provide weather forecasting and climatological data. Such data would be essential for management decisions regarding the health and safety conditions for employees and the public.

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:

- Promote cost-effective support for all DOE facilities;
- Plan for future needs, requirements, and missions;
- Advocate awareness of atmospheric science applications and benefits to DOE; and,
- 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*.

Space Weather Activities

Los Alamos National Laboratory is involved in a full spectrum of space weather activities. LANL's responsibility begins with the design, fabrication, testing, and integration of space hardware on United States satellite assets. LANL is also responsible for the collection, analysis, and archiving of data from those instruments, and for providing value-added data products, theory, simulation, and expertise to end-users. DOE's National Nuclear Security Administration (NNSA) funds the activities described here in accordance to a Memorandum of Understanding with other United States agencies, such as the DOD. The two primary programs that provide space weather data and make them available to a broad user community are: (1) several series of classified geosynchronous satellites and (2) the Global Positioning System (GPS).

The geosynchronous data set at LANL spans more than 26 years (two complete solar cycles) of energetic particle data and 13 years (1989-present) of complete energy coverage, from nearly zero eV to many MeV. The current generation of LANL/GEO satellite instruments include three particle detectors--(1) the Magnetospheric Plasma Analyzer (MPA), (2) the Synchronous Orbit Plasma Analyzer (SOPA), and (3) the Energetic Spectrometer for Particles (ESP). Using funding from the NSF Space Weather Program and Boeing Corporation, LANL has produced a set of "merged" data from the MPA, SOPA, and ESP detectors and provided those data to NSF, Boeing, and other interested agencies and researchers.

The GPS consists of 24 satellites at 55 degree inclination orbits with a period of 12 hours. GPS is best known for its navigational mission and for the ability to measure ionospheric total electron content (TEC) along the line of site from a ground station to a satellite. The GPS satellites, however, have

an additional space weather capability provided by energetic particle detectors, which measure the energetic particle radiation environment. To date, the GPS energetic particle data have primarily been used in studies of the Earth's relativistic electron belt. A major change is planned for this program as the Burst Detector Dosimeter (BDD) instruments will be replaced by Combined X-Ray Dosimeters (CXD). BDD instruments were flown on 4 of the 24 GPS satellites, providing simultaneous coverage from four spacecraft. CXD instruments will be flown on every GPS IIF spacecraft, eventually providing a constellation of 24 simultaneously operating energetic particle detectors measuring the Earth's radiation belts. When complete, the GPS constellation will represent the largest operational fleet of space weather platforms in existence.

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

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 WFMIS inputs remain the same with Remote Automatic Weather Station (RAWS) and National Lightning Detection Network (NLDN) information. Additional fire management information is summarized and made available at the Western Regional Climate Center (*www.wrcc.sage.dri.edu*) and the United States Forest Service Wildland Fire Assessment System (*//svinet2.fs.fed.us/land/wfas/*).

The BLM's RAWS Program primarily collects meteorological data for fire weather forecasting. In past years, the network also provided considerable support to nonfire entities and was operated year around. 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 around operation of the entire network. The BLM's Resource Management and Oregon O&C (West-Side) RAWS networks will continue to operate and to be supported as in the past. These networks are much smaller and have specific program requirements that differ from fire management.

In 1997, the BLM began contracting with a private vendor via the National Weather Service for lightning location data. Data is received at the NIFC in Boise, Idaho and placed on the BLM WFMIS for qualified user access.

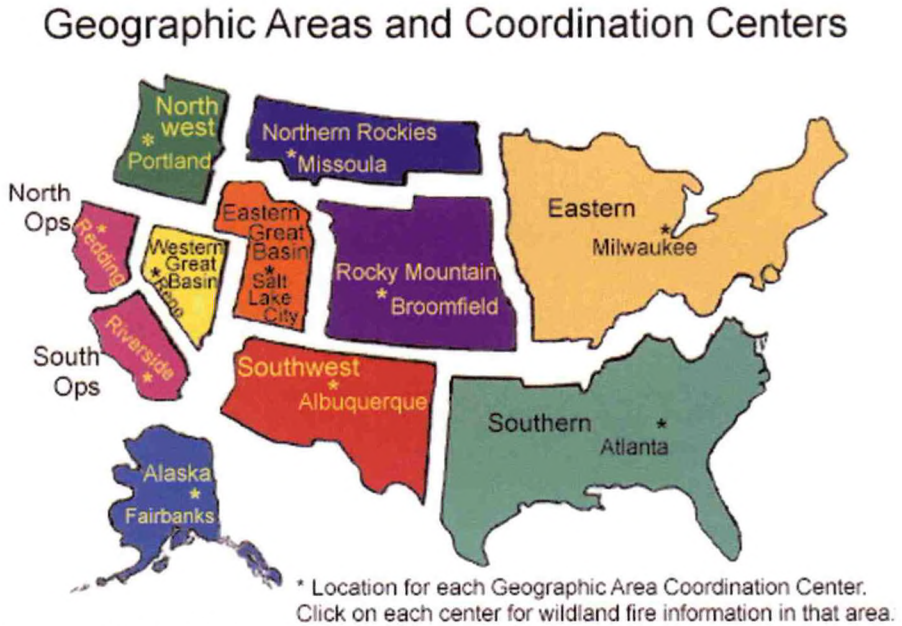


Figure 3-DOI-1. National Interagency Coordination Center coordinates with the GACCs for wildland fire supplies and resources.

Current plans are to continue the operation of the Alaska Automatic Lightning Detection System as an independent government-owed and operated system.

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, the BLM also conducts 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.

During the 1999 fire season, the Remote Sensing/Fire Weather Support Unit began a 2-year "proof of concept" effort with a portable weather station referred to as the Fire RAWS (FRWS). FRWS are intended for use on or near the fireline and are rapidly relocated to points desired by Fire Behavior Analysts (FBA's) for real time weather data. Due to the extreme fire season in both 1999 and 2000, the FRWS was used extensively and was found to be a valuable asset for firefighter safety and fire weather forecasting.

Currently, seventeen FRWS systems are cached at NIFC for use during the 2001 season. Prescribed Fire managers are encouraged to call for information pertaining to weather window prescriptions. FRWS collect, store, and forward data by interrogated voice radio with new data available every fifteen minutes. Satellite data can be retrieved from the BLM/NIFC website. Hourly satellite data is available to Fire Weather Forecasting Staff for spot forecasts and fire support from all central locations (GACC's, NIFC, etc.).

National Park Service

The Park Service monitors air quality and visibility in several national parks and monuments (Figure 3-DOI-2). 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.

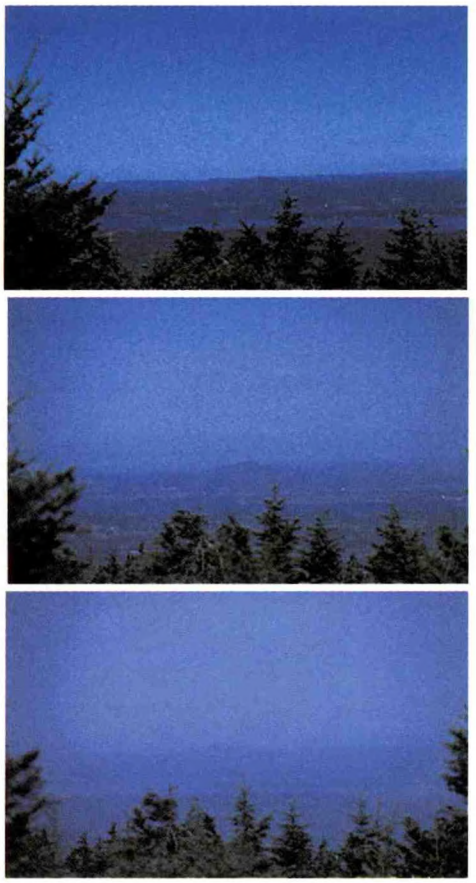


Figure 3-DOI-2. Visibility impairment from air pollution at Acadia National Park, Maine. Top: Clear; middle: moderate; bottom: hazy

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.

The Fish and Wildlife Service Air Quality Branch and the NPS Air Resources Division operate under an interagency agreement and are collocated in Lakewood, Colorado. Expertise from both agencies is pooled to address the air quality issues that are the responsibility of the Assistant Secretary of the Interior for Fish and Wildlife and Parks (Figure 3-DOI-3).

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 5130 remote Data Collection Platforms. The data are transmitted to Wallops, Virginia, via GOES and rebroadcast to a domestic communication satellite (DOMSAT). Data are received from the DOMSAT by local readout ground stations (LRGS) procured by the Geological Survey under a 1992 contract. The 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 atmos-

pheric deposition on water quality and the aquatic environment.

The USGS is carrying out a joint research program with NASA and the University of Washington, Seattle, WA, Electrical and Civil Engineering Departments to measure snowpack water equivalent or snow depth using satellite passive microwave observations from the Defense Meteorological Satellite Program SSM/I sensor. Unlike observations in the visible bands, passive microwave observations are independent of cloud cover and solar illumination and respond to both snow depth and snowpack grain size. The satellite observations are being compared to snowpack data from a variety of sources: USDA/NRCS automatic SNOTEL sites; NOAA/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 to be used in near real time water resource assessments and in climatological studies based on snow pack distributions determined from the two decade long satellite record. The investigation is developing techniques to utilize algorithms that include the effects of grain size metamorphoses and to incorporate these algorithms into hydrologic models.

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 program on three benchmark glaciers representative of different climatic zones of the western United States, one in Washington, one on the south coast of Alaska and one in the interior of Alaska. At each glacier the program measures the winter snow accumulation, summer snow and iceablation, air temperature, and runoff in the glacier basin. Analysis of this 39 year long

Figure 3-DOI-3. Air pollutants emitted by human-made sources affect natural resources of FWS lands.

record is providing a greater understanding of the climate variability and its effects on water resources of the western United States. The record clearly shows the effects of changing winter precipitation patterns associated with El Niño and La Nina events. In addition, the record from South Cascade Glacier, in Washington State, indicates that we are returning to the cool phase of the Pacific Decadal Oscillation. Both the snowpack and glaciology program now incorporate data supplied by the intelligence community through the coordination of the Civil Applications Committee (CAC).

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 Global Positioning System (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*" (FCMP10-1993) which was prepared by the OFCM Committee for Space Environment Forecasting.

The Survey participates in the Working Group for Volcanic Ash (WG/VA) of the OFCM. 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 volcanoes in the United States; of the 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 to bring 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 (Figure 3-DOI-4).

Internationally, the OFCM's WG/VA supported expansion of Survey 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 value - fly international Northern Pacific Routes near these historically active volcanos. About 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.

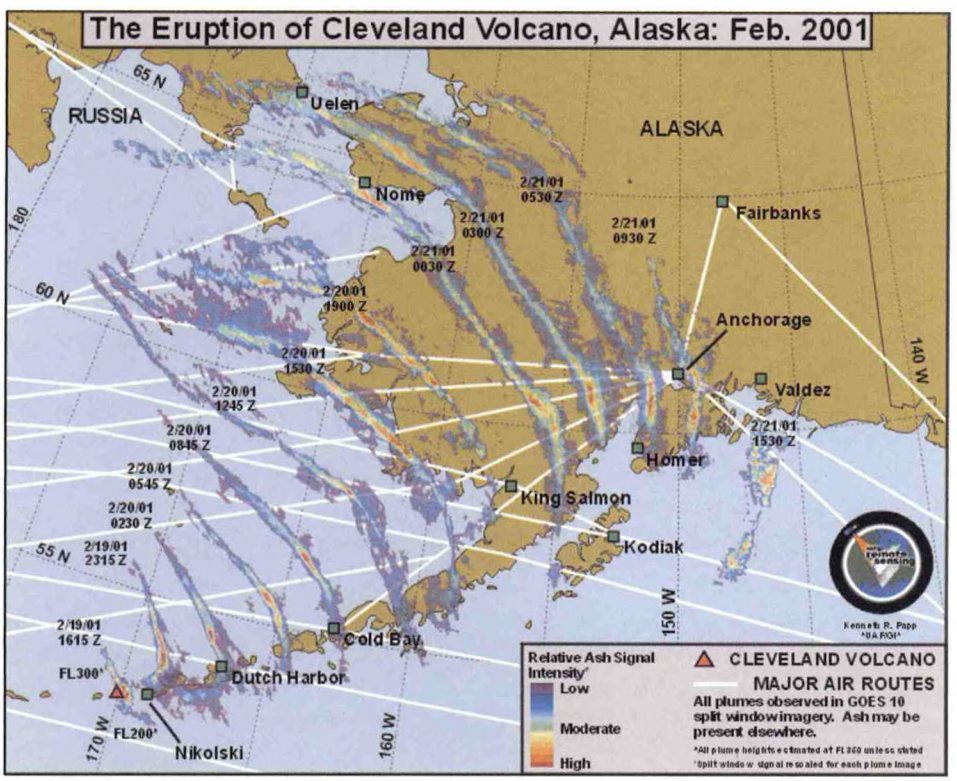


Figure 3-DOI-4. Composite image shows the relative movement of the February 19, 2001 eruption cloud from Mt. Cleveland as observed by the GOES 10 satellite. The first image at 1615 UTC on 2/19/01 is approximately 2 hours after the initial eruption start time. Over time, this first plume became bifurcated, or split, and sent ash to the southeast up to FL200 (20,000 ft.) and to the northwest up to FL300 (30,000 ft.). After this time, the plume rose to FL350 (35,000 ft.). Times are listed in UTC (or Z).

Bureau of Reclamation

The Bureau of Reclamation (Reclamation) activities requiring the collection and use of meteorological data include water supply forecasting, snowpack water equivalent assessment, river system management, reservoir operations, irrigation scheduling, drought status assessment, flood hydrology, and projects related to hydroelectric energy resources. One example of such an ongoing activity within the Science and Technology Program is the Watershed and River System Management Program (WaRSMP), which is being developed in partnership with the USGS. This program provides a data-centered framework for science-based water resources decision making. Major components are:

- Hydrologic Data Base (HDB),
- Modular Modeling System (MMS),
- RiverWare river system modeling framework,
- Stochastic Analysis, Modeling and Simulation (SAMS) system, and
- Agricultural Water Resources Decision Support (AWARDS) and Evapotranspiration Toolbox (ET Toolbox) system.

Hydrologic modeling: SAMS is being used in WaRSMP to assist water resource managers in developing likely hydrologic scenarios for water supplies. It allows users to test various water resources management strategies, including extreme drought and high flow scenarios which haven't been encountered in the historical period of record.

The RiverWare and HDB data-centered decision support system enables water managers to examine a variety of observed and forecast hydrologic scenarios using hourly, daily, or monthly data within the legal and physical constraints on operations of the river system. This model provides a holistic management tool for watershed and

river systems, in order to meet a variety of competing demands for water. Each new river system requires considerable development work (2-3 years) for RiverWare and HDB implementation. However, such a system can provide for efficient water operations management, and is especially useful during periods of drought and surplus - as demonstrated by the recent "Colorado River Interim Surplus Criteria: Final Environmental Impact Statement". (*www.lc.usbr.gov/~g4000/surplus/SURPLUS_FEIS.HTML*)

Current Reclamation Science and Technology Program projects under WaRSMP include:

- Planning and developing HDB, MMS and RiverWare systems for the Gunnison, San Juan, Rio Grande, Yakima, and Truckee river systems;
- SAMS integration and testing for the Colorado River Basin;
- Implementing AWARDS systems to improve the efficiency of water management and irrigation scheduling for the Tualatin Project, Upper Columbia project areas, and Lower Colorado area;
- Developing the AWARDS/ET Toolbox system in the Middle Rio Grande and providing 24-hr water use estimates for input, via the Corps of Engineers' Hydrologic Engineering Center Decision Support System or a new HDB, to the Rio Grande RiverWare; and
- Implementing similar AWARDS/ET Toolbox systems with input to local HDBs and RiverWare systems in the Upper Columbia, Lower Colorado, and possibly the Truckee-Carson areas.

An additional product of the WaRSMP is the Hydrologic Modeling Inventory (HMI) which provides general technical information and contacts for a wide variety of water resources models presently in use. The HMI is being expanded and can be accessed on the Web (*www.usbr.gov/hmi*).

Decision Support Systems: The AWARDS/ET Toolbox for the Middle Rio Grande is a good example of decision support tool development to enhance river system management. An AWARDS system was implemented to meet a critical need for improvement in calculating and forecasting daily agricultural and riparian water use demands along the Middle Rio Grande. This Internet-based automated information system assists water managers and users by providing easy access to daily rainfall and crop water use estimates. These estimates are based on real-time data obtained from NEXRAD radar systems and automated weather stations. The NEXRAD precipitation products use the NWS's Hydrologic Rainfall Analysis Project (HRAP) grid, which has a resolution of about 4km^2.

The ET Toolbox builds on the AWARDS system, adding GIS land use to specify crop, riparian, and open water acreage within each grid cell. The primary purpose of the ET Toolbox is to accumulate the grid cells' daily rainfall and water use estimates within specified river reaches. These estimates are presented on the Internet (*www.usbr.gov/rsmg/nexrad*) and imported into RiverWare, which is the river modeling and water accounting system used by the Upper Rio Grande Water Operations Model. Figure 3-DOI-5 (below) is an example of an ET Toolbox pop-up graph sum-

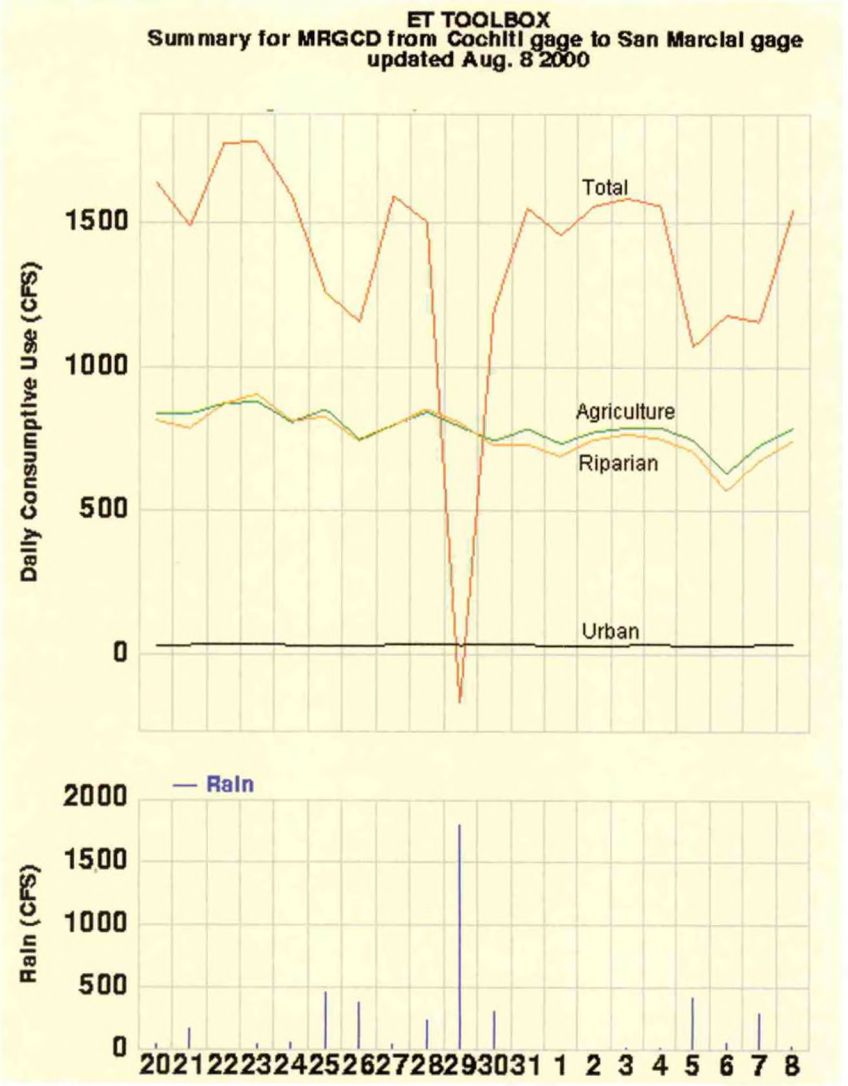


Figure 3-DOI-5. Example of a Middle Rio Grande Evapotranspiration Toolbox pop-up graph for daily water consumption use.

mary of daily water consumptive use for the area from Cochiti Dam to San Marcial, New Mexico, for a time period in July-August 2000. The figure shows the effect of a heavy rainfall event on 29 July; the effects of lighter rainfall events can also be noted.

Rio Grande water operations managers at Reclamation's Albuquerque Area Office used the ET Toolbox website several times a day to direct critical water releases for the threatened Silvery Minnow and to meet other irrigation demands during the severe 2000 drought. They found that the ET Toolbox information was "invaluable" for their decision making. System enhancements were made in near real time to provide specialized support.

Radar meteorology: A new version of Reclamation's Snow Accumulation Algorithm (SAA) was developed under the auspices of the GEWEX Continental-Scale International Program (GCIP) and Reclamation's Science and Technology Program. This model uses real-time NEXRAD Level III radar data and was deployed in the north-central United States as a demonstration project during cool seasons from 1998-2001. It provides graphical distributions of snow water equivalent (SWE) and snow depth (SD) estimates on the Internet. The end goal is to improve snowpack water equivalent assessments and input SWE into the river model at the NWS Missouri Basin River Forecast Center, which will lead to more accurate streamflow forecasts.

Recently the SAA was improved by several major modifications, which primarily identify different precipitation types (snow, melting snow, rain). The inclusion of different precipitation types, led to renaming the SAA as the Precipitation Accumulation Algorithm (PAA). The former SAA range correction employed a mean Vertical Profile of Reflectivity (VPR) recast as a function of range. The PAA restores the adjustment with a true VPR based on clearance between the radar beam center and the terrain surface.

In the PAA, precipitation phase in the radar beam and at the surface is classified into three types: dry snow, melting snow (slush), and rain, based on hourly model sounding altitudes of the highest 0°C and lowest +4°C levels. If any part of the radar beam is between those altitudes, it is considered contaminated by bright band effects. If the surface temperature is warmer than +4°C, snow depth SD is not accumulated because rain is assumed. The relationship between equivalent radar reflectivity Z_e and rainfall rate R is approximated by the power law $Z_e = \alpha R^{\beta}$. The three precipitation type classes in the PAA have different α but β remains constant (2.0). Tests are also being implemented in the PAA to identify virga, or precipitation that is not reaching the ground.

Improved quantitative precipitation estimates are expected from PAA - which will lead to better watershed precipitation water volume and runoff estimates for the AWARDS system. This will provide water managers with near real-time estimates of possible sidewash inflows into the mainstem of river systems (via a hydrologic runoff model).

Water conservation efforts: Reclamation is a partner with several large western municipal water providers in the study of benefits from the implementation of water conserving landscaping. The study known as the National Xeriscape Demonstration Program includes the development of a numerical evapotranspiration-based model that will use municipal logistical and climatological data as inputs to develop benefit estimates for municipalities of the West. Some early suggestions from the study point to inefficient irrigation by homeowners caused by inefficient systems and operation, in addition to using high water-consuming landscape plants. More study is needed on development of "smart" irrigation scheduling systems and centralized control by water providers.

During abnormal regional climate conditions, Reclamation meteorologists assist water managers by evaluating environmental information and providing guidance based on the NOAA Climate Prediction Center's (CPC) Weekly Threats Briefing updates and CPC's seasonal and annual climate forecasts. Special related studies are done upon the request of Reclamation water operations managers, policy team leaders, and cooperating agencies.

Instrumentation: Currently, Reclamation's HYDROMET system collects data from approximately 400 hydrometeorological data collection platforms (DCPs) which transmit data in the "real-time" through the GOES to the Bureau's DRGS in Boise, Idaho. AGRIMET is another network of 60 DCPs dedicated to analysis of crop water use and water conservation in the Pacific Northwest. Data collected and products created in Boise are electronically transferred to other Bureau, Federal and state offices.

Minerals Management Service

The Minerals Management Service's 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 three 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 end in late 2001. 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.

Upon request by MMS, the oil and gas industry has undertaken an aerometric monitoring program for the offshore area within 100 km of the Breton National Wilderness Area. Six monitoring stations were established, five of them located on offshore platforms. All of them collect surface meteorological data. Four of the sites have radar profilers with RASS. Three of the sites also collect air quality data. Data collection started in September 2000 and will continue through August 2001. The purpose of the program is to obtain a data set for air quality modeling in the area.

Bureau of Indian Affairs

The Bureau of Indian Affairs collects atmospheric data to evaluate potentially irrigable IndianTrust 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 March 2001, it had been ratified by 186 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 pollution 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 continue to evolve over the next few years. In the area of pollutant deposition, the evaluation of nitrogen, oxidant, sulfur and aerosol chemistries will help to 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 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 atmospheric transport are being 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 for Tropospheric Ozone, now identified 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. A specific application involves computer graphics-based solar radiation exposure modeling. Three-dimensional graphics modeling software is used to display a near-photographic-quality human model, and to illuminate the model with a simulated sunlight

source. Since the American Cancer Society reports that over 80 percent of skin cancers occur on the face, head, neck, and back of the hands, modeling human exposure to solar radiation requires that exposure calculations be anatomically resolved. The calculation of light illumination for various receptor points across the anatomy will provide information about different exposures as a function of model posture, orientation relative to the sun, and sun elevation. This kind of research will provide a "dose" factor needed to develop dose-response functions for skin cancer, immune system suppression, and cataract formation.

In addition to these major areas, dispersion models for inert, reactive and toxic pollutants are under development and evaluation on all temporal and spatial scales, e.g., indoor, urban, complex terrain, mesoscale, and regional. Other efforts include construction and application of air pollution climatologies; modeling of agricultural pesticide spray drift and of fugitive particles from surface coal mines; modeling of trace metal deposition to the Great Lakes, nutrient deposition to Chesapeake Bay, and mercury deposition to the Florida Everglades; modeling of accidental releases of toxic compounds forming dense gas clouds; 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 will be used to continue development and evaluation of these models in the FY 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 is also being used to simulate and develop improved models for open burning and open detonation of surplus and obsolete military munitions.

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/Community Multi-scale Air Quality (CMAQ) modeling project was to develop a "one atmosphere" flexible environmental modeling tool that integrates the major atmospheric pollution regimes in a multi-scale, multi-pollutant modeling system. This system will enable high-level computational access to both scientific and air quality management users for socio-economic applications in community health assessments and ecosystem sustainability studies.

After seven years of development, the Models-3/CMAQ was released in June 1998 and is being updated annually for use by Federal agencies, States, industry, and academia. The latest release occurred in April 2001. It is also intended to serve as a commu-

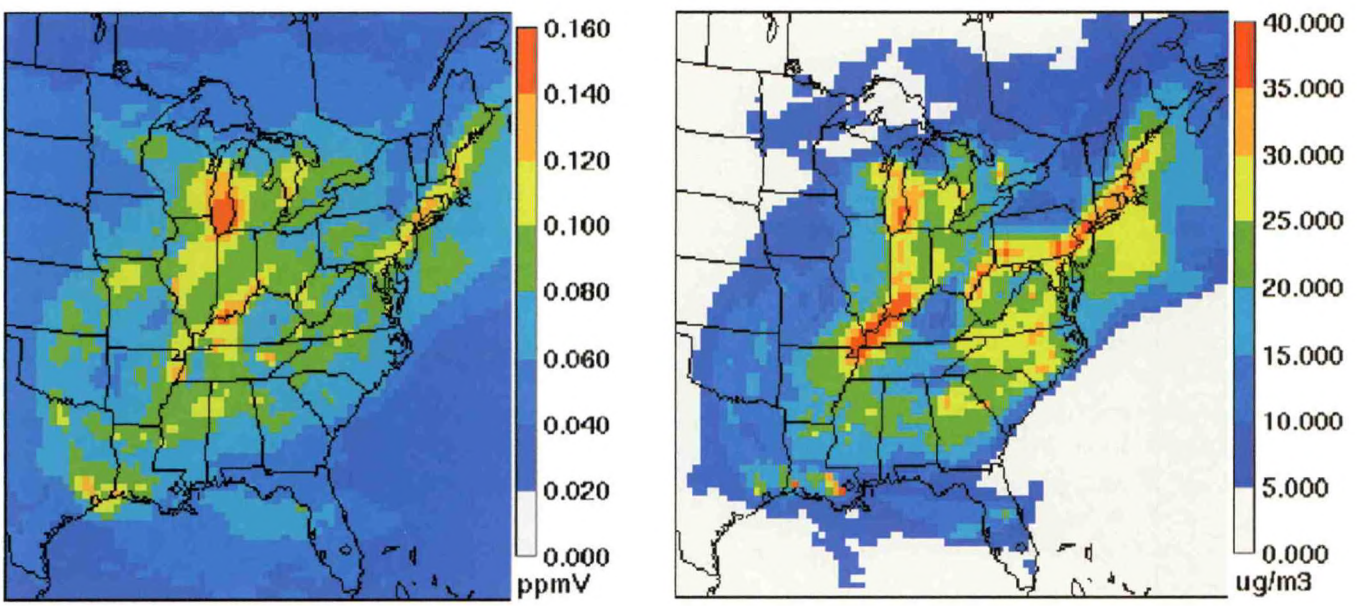


Figure 3-EPA-1. (Left panel) Models-3/CMAQ simulation results for July 13, 1995, for the eastern United States at 36-km grid resolution showing (a) maximum hourly ozone concentration (ppmV) in each grid cell between 7 AM and midnight EDT. (Right panel) 24-hr averages of PM2.5 concentrations (micrograms/m^3) in each 36-km grid cell.

nity framework for continual advancement and use of environmental assessment tools. Models-3/CMAQ, configured for the Windows-NT computer system, is available on tapes from the National Technical Information Service (NTIS). It is 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/*. Figure 3-EPA-1 illustrates Models-3/CMAQ simulation results for ozone and fine particulate matter (PM2.5) for July 13, 1995, over the eastern United States, a period of widespread ambient pollution in this part of the nation.

EPA participation in the interagency Information Technology Research and Development (IT R&D) Program is developing a modeling framework that supports integration of diverse models (e.g, atmospheric, land surface, and watershed) as part of EPA's Multimedia Integrated Modeling System (MIMS) project, described at *http://www.epa.gov/asmdnerl/mims/*. EPA's IT R&D work also enables increased efficiency in air quality meteorological modeling through research on parallel implementation of the CMAQ modeling system.

The evolving 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 include: (1) developing a prototype multiscale integrated modeling system with predictive meteorological capability for transport and fate of nutrients and chemical stressors; (2) enabling the use of remotely sensed meteorological data; and (3) developing a computer-based problem solving environment with ready access to data, models, and integrated visualization and analysis tools for water and air quality management, local and regional development planning, and exposure-risk assessments. Under the MIMS project, a variety of research areas are being pursued such as the integration of the National Weather Service Next Generation Radar (NEXRAD) Stage IV data into watershed modeling applications; enhanced atmospheric dry deposition models; multi-scale, spatially explicit watershed modeling tools; and model-coupling technology for integrating media specific models. The MIMS development extends the open architecture approach demonstrated in the third generation modeling system, Models-3/CMAQ, and is the next generation of modeling frameworks under the IT R&D program.

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 United States/Russia (US/USSR) Joint Committee on Cooperation in the Field of Environmental Protection and under the 1993 Gore-Chernomyrdin Agreement forming the US/USSR Commission on Economic and Technological Cooperation. Other agreements are in place with Canada, Japan, Korea, China, and Mexico, and with several European countries under the NATO Committee on the 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. In-land flooding in the Florida panhandle resulting from Hurricanes Georges.

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 and techniques needed by forecasters at Cape Canaveral Air Station and the Spaceflight Meteorology Group (SMG) at Johnson Space Center (JSC) to support the Space Shuttle and Expendable Launch Vehicle (ELV) programs. The focus is on observing 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), co-located with the Air Force's Range Weather Operations, provides a facility to develop, 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 Space Center's (KSC) frequent 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 (AF), and National Weather Service (NWS) Memorandum of Understanding. AMU tasks during FY 2001 include:

(a) Development and evaluation of statistical forecast tools for winds and ceilings.

(b) Continued evaluation of the Eastern Range Dispersion Assessment System/Regional Atmospheric Modeling System (ERDAS/RAMS).

(c) Development and evaluation of land breeze forecast methodologies.

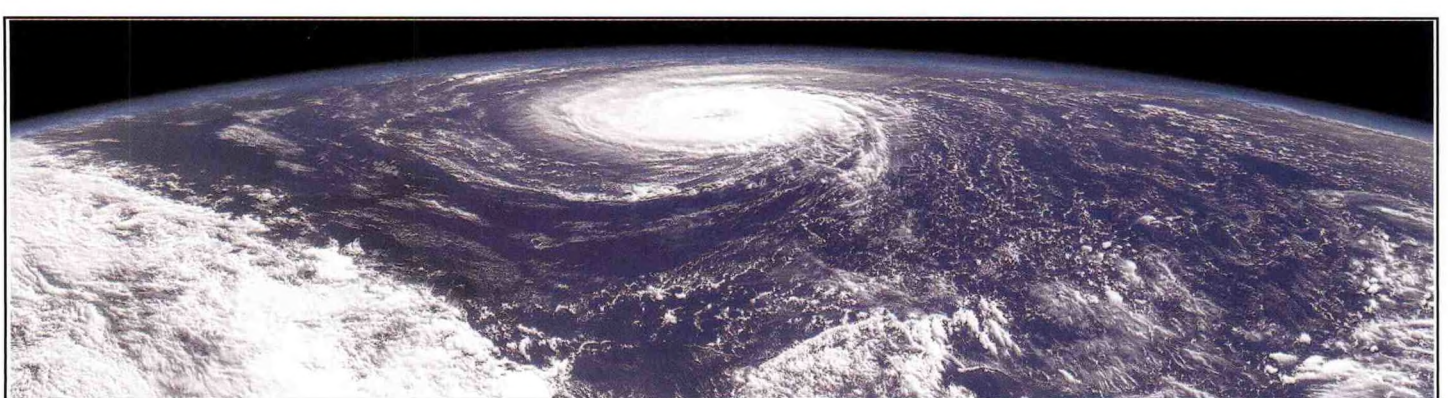
(d) Development and evaluation of thunderstorm anvil forecast methodologies.

(e) Evaluation and implementation of the Neumann-Pfeffer Thunderstorm Probability Index.

(f) Continued evaluation and implementation of a Local Data Integration System (LDIS) at the NWS office in Melbourne, Florida.

(g) Continued development, evaluation and implementation of tools and techniques for most effective use of the AF WSR-74C radar and its SIGMET processor.

(h) Comparison of Lightning Detection and Ranging (LDAR) antenna systems.



(i) Development, evaluation and implementation of a forecast tool for estimating the time of recovery from violations of the Shuttle Low Temperature Launch Commit Criterion.

(j) Development and implementation of software for operational support to the Airborne Field Mill program (see below).

The KSC Weather Office is improving the weather infrastructure at KSC and conducting research to improve operational processes and facilities. In FY 2001, five suites of visibility and soil moisture sensors were installed to the west of KSC to aid in the forecast of morning fog that could impact Shuttle landings. The Weather Office also conducted a major field research program called "Airborne Field Mill" (ABFM) to collect data necessary to relax the lightning launch constraints while making them even safer. ABFM was cooperatively funded by the Shuttle program, NASA ELVs, and AF. The ABFM team includes more than 50 personnel from eleven organizations including other Governmental agencies, NASA Centers, universities and their contractors. Data analysis should be complete and new launch rules proposed by the end of FY 2002.

The KSC Weather Office, the SMG at JSC, and the AMU continue to work on Range Standardization and Automation (RSA) and the new Spacelift Range Systems Contract (SLRS-C). RSA is a major AF program to modernize the Eastern and Western Range infrastructure. SLRS-C will handle sustaining engineering for what RSA provides. Deliveries of weather sensors, models, and control and display systems began in FY 2000 and will conclude in FY 2003. Transfer of the KSC 50 MHz Doppler Radar Wind Profiler to the Eastern Range and modernization of its electronic components is proposed. There are many issues related to the pending changes to the Eastern and Western Ranges' meteorological infrastructures. The AF and NASA weather communities continue to expend significant resources to solve potential major deficiencies. NASA KSC, JSC and Marshall Spaceflight Center 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 mission of NASA's ESE is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. NASA brings to this endeavor the vantagepoint of space, allowing global views of Earth system change. NASA is a provider of objective scientific information, via observation, research, modeling, and applications demonstration, for use by decision-makers in both the public and private sectors. NASA has been studying the Earth from space from its beginnings as an agency. These efforts have led to our current activity of deploying the first series of Earth Observing System (EOS) satellites that will concurrently observe the major interactions of the land, oceans, atmosphere, ice, and life that comprise the Earth system. 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 life on Earth?

A fundamental discovery made during the 20th century, enabled in large part by NASA's global view from space, 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, NASA has worked with other agencies to develop a new, interdisciplinary field of "Earth system science", 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 through which to carry out its mission:

- Science: Observe, understand, and model the Earth system to learn how it is changing, and the consequences for life on Earth;
- Applications: Expand and accelerate the realization of economic and societal benefits from Earth science, information, and technology;
- Technology: Develop and adopt advanced technologies to enable mission success and serve national priorities. These goals are articulated in the ESE Strategic Plan.

NASA and its partners have already made considerable progress in understanding the Earth system. With satellites launched over the past decade, ESE has charted global ocean circulation including the waxing and waning of El Niño, mapped land cover change over the entire globe, illuminated the 3-D structure of hurricanes, and explored the chemistry of the upper atmosphere and the causes of ozone depletion. With deployment of the EOS now underway, ESE is opening a new era in Earth observation from space in which the major interactions

of the Earth system are studied simultaneously to provide a global view on climate change. 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 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.

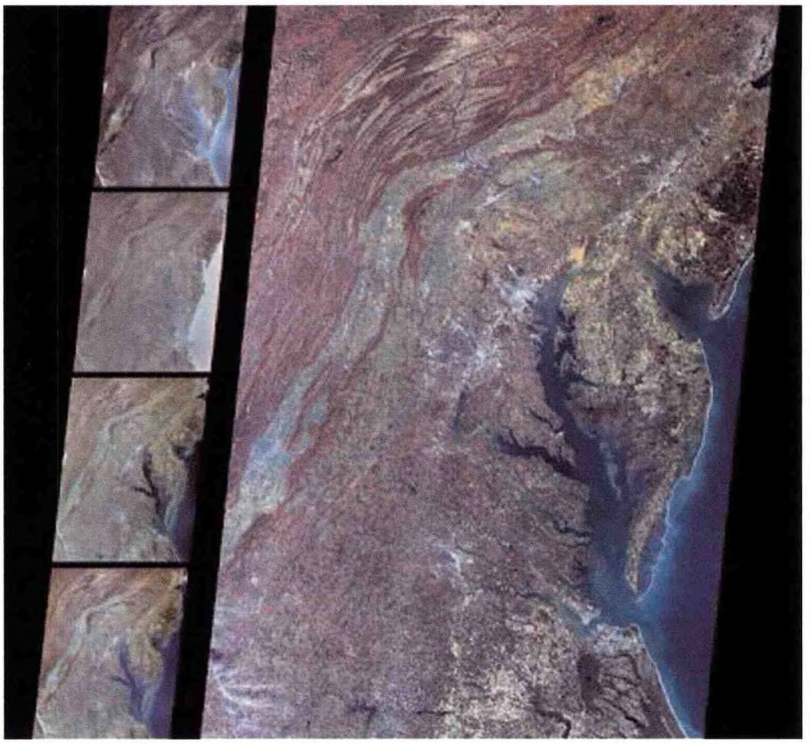


Figure 3-NASA-1. Mid Atlantic states on March 24, 2000 from the Multi-angle Imaging SpectroRadiometer (MISR), on board NASA's Terra satellite. Yellowish smudge at the top of the Chesapeake Bay is likely sediment from the Susquehanna River, flowing into the upper Chesapeake (Source: GSFC web site).

STRATEGY FOR ACHIEVING GOALS

Science

We know that natural and human-induced changes are acting on the Earth system. Natural forces include variation in the Sun's energy output and volcanic eruptions which spew dust into the atmosphere and scatter incoming sunlight. Human forces include deforestation, carbon emission from burning of fossil fuels, methane and soil dust production from agriculture, and ozone depletion by various industrial chemicals. Internal climate factors, such as atmospheric water vapor and clouds, also introduce feedbacks that serve to either dampen or enhance the strength of climate forcing. We also know the climate system exhibits considerable variability in time and space, i. e., both short and long term changes and regionally-specific impacts (Figure 3-NASA-1).

NASA has used the concept of Earth System Science in developing its program. Researchers have constructed computer models to simulate the Earth system, and to explore the possible outcomes of potential changes they introduce in the models. This way of looking at the Earth as a system is a powerful means of understanding changes we see around us. That has two implications for Earth Science. First, we need to characterize (that is, identify and measure) the forces acting on the Earth system and its responses. Second, we have to peer inside the system to understand the source of internal variability--the complex interplay among components that comprise the system. By combining observations, research and modeling, we create a capability to predict Earth system change to help our partners produce better forecasts of change.

Earth system changes are global phenomena. Yet the system comprises many micro-scale processes, and the most significant manifestations are regional. Thus, studying such changes requires a global view at regionally discerning resolutions. This is where NASA comes in, bringing the unique capability to study planet Earth from the vantagepoint of space. To characterize the forces acting on the Earth system and its responses, understand the source of internal variability and predict Earth system change, NASA must observe the Earth, conduct research and analysis of the data, model the data and synthesize the information into new knowledge. Where we are on this knowledge "life cycle" determines the strategy for our investment decisions.

The ESE is pursuing a targeted research program, focused on a set of specific science questions that can be addressed effectively with NASA's capabilities. ESE formulates comprehensive research strategies that can lead to definitive scientific answers and potentially to effective applications by other entities.

The key Earth Science research topics sponsored by NASA follow from this view of the Earth as a system. Thus they are grouped into categories of: (a) variability in the Earth System, (b) forces acting on the Earth system, (c) responses of the system to change, (d) consequences of change, and (e) prediction of future changes. Complicating this seemingly linear construct is a set of feedbacks; responses to change often become forces of additional change themselves. This conceptual approach applies in essence to all research areas of NASA's Earth Science program, although it is particularly relevant to the problem of climate change, a major Earth Science-related challenge facing our nation and the rest of the world.

The ESE has articulated an overarching question and a set of strategic science questions reflecting this Earth system approach, which its observational programs, research and analysis, modeling, and advanced technology activities are directed at answering.

- *How is the Earth system changing, and what are the consequences for life on Earth?*
- *How is the global Earth system changing?*
- *What are the primary causes of change in the Earth system?*
- *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 future changes in the Earth system?*

ESE's Research Strategy for 2000-2010 describes NASA's approach to answering these questions. 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. 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.

Applications

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 ultimately result in practical applications beneficial to all citizens. Examples of these applications may include: quantitative weather and hydrologic forecasts over an extended range of one to two weeks; prediction of seasonal or longer-range climate variations; the prediction of impacts of environmental changes on fisheries, agriculture, and water resources; global air quality forecasts, and natural hazards risk assessments. NASA ESE has a role in demonstrating the potential applications.

ESE continues to build a viable applications, education and outreach program that bridges our focused Research and Analysis (R&A) and mission science investments towards demonstration of new remote sensing data products for industry and regional and local decision makers. The emphasis is to focus on the dissemination of information to non-traditional Earth science customers, such as states, counties and regional managers and decision-makers. A base program is funded to put the essential tools in place and pilot several key demonstration projects. Eventually we hope that our demonstration of this concept will allow products to reach a much broader user base -practically every state in the Union.

A series of regional workshops have been held around the Nation to enable a wide variety of state and local government users to explain the challenges they face that might be addressed with tools based on satellite remote sensing. One result is the establishment of regular, open, competitively selected opportunities for these organizations to propose partnerships with NASA, academia and industry to demonstrate new applications of Earth science to specific problems. Successful demonstrations are expected to lead to new commercial/state and local government transactions, while ESE moves on to the next new demonstration activity.

Technology

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), 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

Figure 3-NASA-2. The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the National Space Development Agency (NASDA) of Japan designed to monitor an study tropical rainfall and the associated release of energy that helps to power the global atmospheric circulation shaping both weather and climate around the globe (Source: GSFC Web site)

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 investments 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.

MISSION IMPLEMENTATION

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 Explorer missions that are nearing completion. In addition, we are 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 ESE 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.

Realizing Scientific Return from Past Investments

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. France and the United States collaborated on the Ocean Topography Experiment (TOPEX/ Poseidon), launched in 1992, to study ocean topography and circulation. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation (Figure 3-NASA-2). Also in 1997, ESE began purchasing ocean color data from a commercial vendor based on our joint investment in the Sea-viewing Wide Field Scanner (SeaWiFS) instrument (Figure 3-NASA-3).

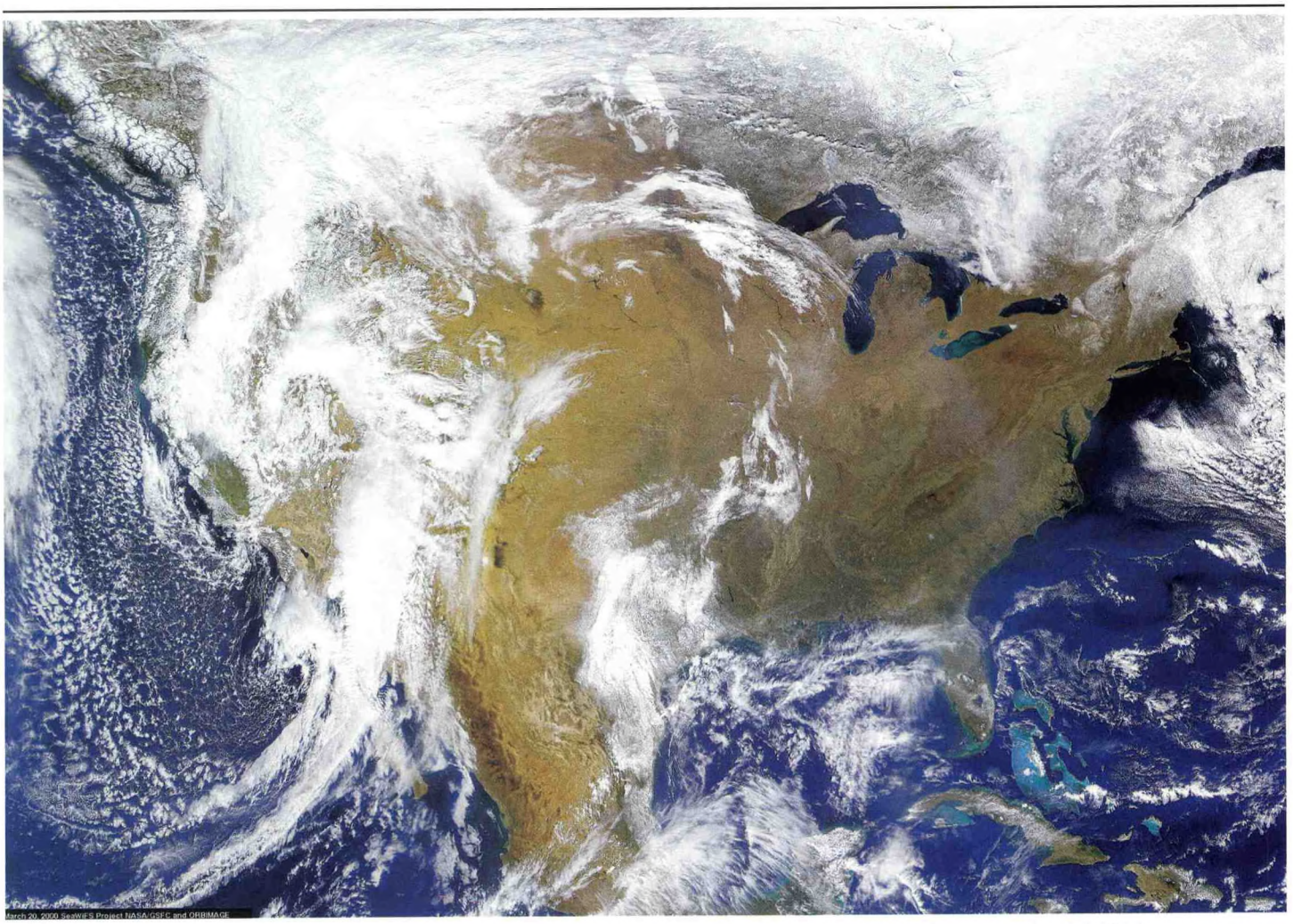


Figure 3-NASA-3. High resolution imagery from NASA's Sea-viewing Wide Field Scanner (SeaWiFS) instrument

Opening a New Era in Earth System Science with the Earth Observing System

The EOS, the centerpiece of Earth science, is a program of multiple spacecraft (the Terra, Aqua, Aura, Landsat-7, Jason-1, ICEsat, ACRIMSAT, Seawinds, SORCE, SAGE III, QuikSCAT, and follow-on missions) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change.

Terra was recently launched on December 18, 1999. Terra is providing key measurements that are significantly contributing to our understanding of the total Earth system. The instrument complement is obtaining 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 are used for global change research, regional environmental change studies, and other civil and commercial purposes.

The QuikSCAT spacecraft was launched in June 1999. QuikSCAT, carrying instruments to collect sea surface wind data, is filling the gap in such critical data between ADEOS 1, 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 2002 with the delay due to a failure of the Japanese H-IIA 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 Earth Explorers Program contains a series of focused, rapid development missions to study emerging

science questions and processes utilizing innovative measurement techniques as a complement to the systematic measurements made through the EOS. The Shuttle Radar Topography Mission (SRTM) flown on STS-99 in February 2000 was a joint NASA and National Imaging and Mapping Agency (NIMA) mission to create a near-global, high-resolution digital elevation topographic map of the world. The data from the SRTM will allow scientists in federal, state and local agencies and academia to study the terrain for basic research in the areas of ecology, geology, geodynamics, hydrology and atmosphere modeling.

Some missions in this category are Earth System Science Pathfinder (ESSP). Four ESSP missions have been selected: (1) Gravity Recovery and Climate Experiment (GRACE) with launch in 2001, (2) Vegetation Canopy Lidar (VCL) with launch TBD (launch date under review), (3) CloudSat with launch in 2003, and (4) the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations-Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) with launch to be determined (launch date is under review). The Earth Explorers Program also encompasses various missions, which are developed in response to requirements that provide or continue highly focused Earth science process measurements. This currently is QuikTOMS (TOMS FM-5) with launch planned for June 2001(Figure 3-NASA-4). Because the launch date for Triana remains uncertain until the Shuttle manifest becomes definitized, Triana will be placed in storage following completion of spacecraft development. In addition, the University Earth System Science (UnESS) program is being cancelled to fund immediate priorities in the Earth Science budget. A small amount of funding will be retained for these activities to complete contractual obligations associated with proposal evaluations.

EOS and related missions in development and preparation for launch through 2003 are:

- QuikTOMS (2001) - Atmospheric ozone and aerosols
- SAGE III (2001) - Stratospheric aerosols and gases experiment
- Jason (2001) - ocean topography; successor to TOPEX/ Poseidon
- Aqua (2001) - atmospheric temperature and humidity, clouds, sea surface temperature, biosphere
- GRACE (2001) - time variations of Earth's gravity field
- ICEsat (2001/ 02) - ice sheet topography
- SORCE (2002) - solar irradiance
- SeaWinds (2002) - on Japan's ADEOS II satellite; ocean winds successor to QuikSCAT
- Vegetation Canopy Lidar (TBD) - Forest canopy height
- Aura (2003) - Upper and lower atmospheric chemistry
- Cloudsat (2003) - 3-D cloud profiles
- PICASSO-CENA (TBD) - 3-D aerosol profiles

The EOS Data and Information System (EOSDIS) is operating the EOS satellites now in orbit, and retrieving flight data and converting it into useful scientific information. EOSDIS is nearly complete; remaining segments are timed for release to support the upcoming launches of EOS missions through Aura in 2003. Following the recommendation of the National Research Council, 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 is part of a broader analysis of how ESE's approach to data

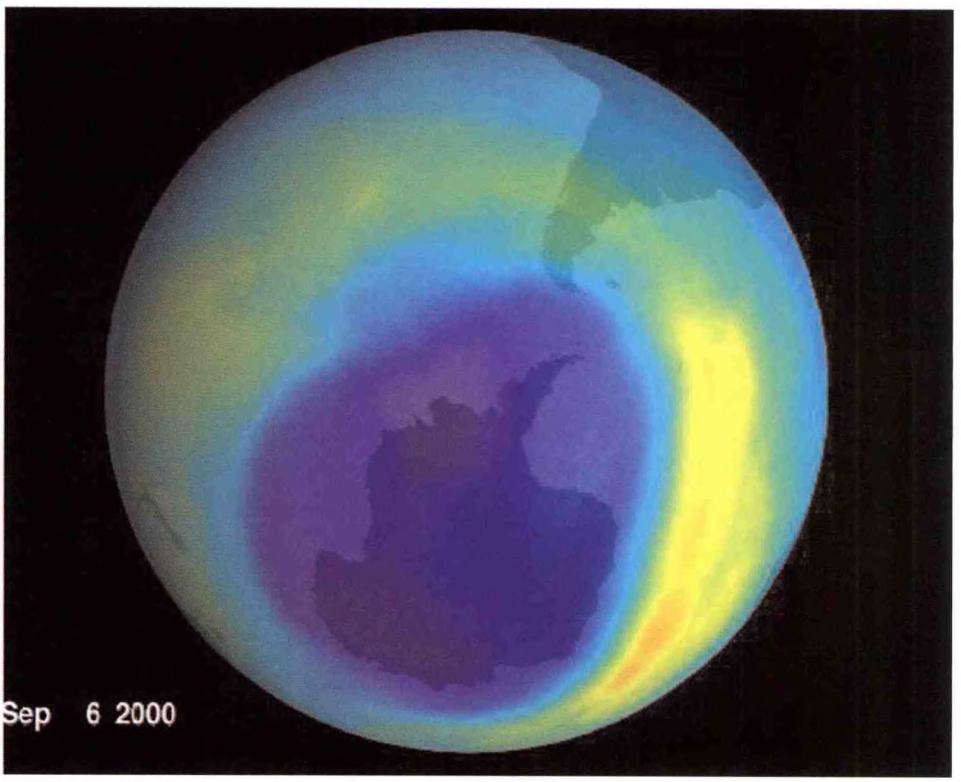


Figure 3-NASA-4. Largest-ever Ozone hole, roughly three times the size of the United States, was detected on September 6, 2000 by NASA's Total Ozone Mapping Spectrometer (TOMS) (Source: GSFC website)

and information systems services should evolve in the future. 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, Earth science information partners, and efforts are under way to fuse science data, socio-economic data and other data sets that can be "geo-referenced" in readily understandable data visualizations.

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.

Preparing for the Next Decade of Scientific Discovery

In parallel with deploying EOS, NASA ESE is looking ahead to determine what will be the important Earth science questions in the next decade, and which require NASA's leadership to be answered. Drawing on existing reports of the National Academy of Sciences and the state of progress in current scientific endeavors, ESE has developed a Research Strategy for 2000-2010 that articulates a hierarchy of one overarching question, five broad subordinate questions, and twenty-three detailed questions that can and should be tackled over this decade. For each, the Research Strategy defines the observational requirements, which in turn provide the basis for definition of candidate missions to be pursued. An early, high priority in this timeframe is the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP), which will serve to provide continuity with the Terra and Aqua missions as well as a demonstration of instruments for the converged weather satellite program. 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 AF. Another priority is the Landsat Data Continuity Mission to succeed Landsat-7. As with Landsat-7, this mission is being planned in partnership with the USGS. NASA and USGS are also working with industry to explore the potential for a commercial purchase of Landsat-type data to meet this data continuity requirement.

In NASA's FY 2001 appropriation, Congress included funds for concept definition work for potential missions to observe global precipitation, global earthquakes, and global tropospheric winds. Studies are underway, with further definition work anticipated to proceed in FY 2002. Also in FY 2002, ESE plans to begin similar definition activities for observation of global ocean topography and ocean surface winds to succeed Jason and SeaWinds on ADEOS II, respectively. Beginning in FY 2001, NASA is soliciting its third round of ESSP missions, with selection(s) anticipated in FY 2002.

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, we will ask commercial industry to come forward and offer science-quality data that meet NASA requirements for NASA to purchase. 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.

Finally, along with space-based observations, ESE will pursue a guided evolution of data and information system services to support missions and research in the next decade. NASA's FY 2001 appropriation also included funds to develop the "NewDISS" concept for this evolution. Studies in this arena are underway as well.

PARTNERSHIPS ARE ESSENTIAL TO SUCCESS IN EARTH SCIENCE

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 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.

SPACE WEATHER The Living With A Star (LWS) Program (Figure 3-NASA-5) addresses the linkage between three fundamental questions of the NASA solar-terrestrial physics program's the Sun Earth Connection (SEC) program:

- How and why does the sun vary?
- How does the Earth respond to solar variations?
- How does solar variability affect life and society?

The SEC Program strives to understand the physical processes and connections that control the dynamics of the Sun-Earth connected system. The system dynamics are driven by violent solar bursts, long term solar variability, and instabilities of the magnetized Earth-space, geospace. LWS is grounded in service to humanity and it's technological systems. It is based on solving the specific problem of being able to predict solar variations and the effects of those variations on humanity and human systems. LWS will integrate results from existing and future space missions as they contribute to the SEC system level goals. The program is based on providing the understanding necessary to predict what will happen where and when to the heliosphere, geospace, and Earth's

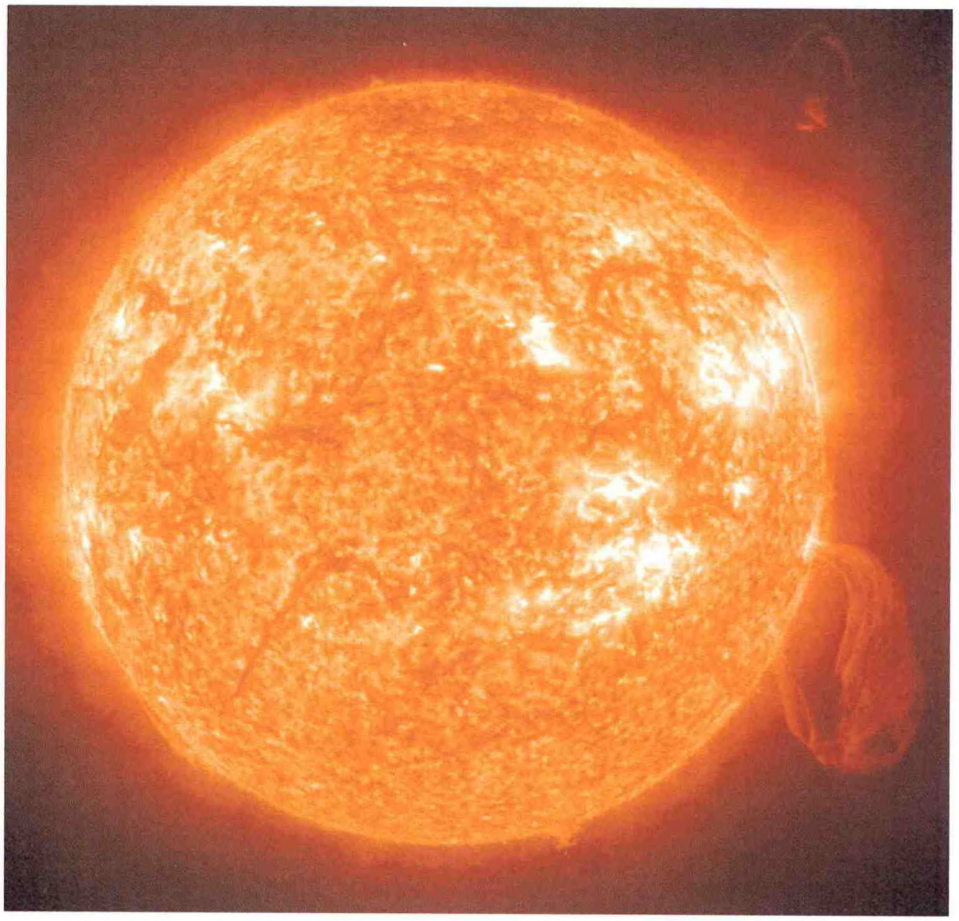


Figure 3-NASA-5. Bulbous prominence -- A large, twirling prominence taken on February 12, 2001. Prominences are huge clouds of relatively cool dense plasma suspended in the Sun's hot, thin corona. At times, they can extend outward and break away from the Sun's atmosphere. This image shows ions of helium heated at 60,000 degrees C.

climate given observations of conditions on the Sun.

While both existing SEC programs and LWS are basic research, there are some significant differences in concept and approach. The primary difference is that in addition to the traditional input from the space science community, LWS derives requirements from Earth science, human spaceflight, industry and other federal agencies (National Space Weather Program, Office of the Secretary of Defense Space Weather Architecture, DOD, NOAA, FAA). The LWS Program has characteristic features: there is a significant component that deals with specification models; what is the environment as a function of space and time. This is an important need for industry that must build spacecraft that survive, and to provide anomaly resolution. There is a need for human spaceflight radiation protection. Finally, there is the issue of prediction, which is the more traditional science.

The program priorities are (numbers indicate priority rank):

(1) Solar influences on Global Change: Global change is the single most important environmental problem facing humanity. This issue involves major national and international policies because of the potential economic impacts of global change and/or mitigation actions. Objectives:

- Determine how and why the Sun varies (for assessment of past and future role in global climate change).
- Identify and understand mechanisms by which solar variability affects terrestrial climate (and possibly weather).

(2) Space environmental "climate" data (e.g., specification models):

- Needed for design of cost-effective systems with minimal or no sensitivity to space weather.
- The goal is to have economical "all weather" systems; not to be dependent on predictions.

(3) Nowcasting space environment:

- For rapid anomaly resolution for space and communication/navigation systems--if an anomaly is due to a known space environmental effect, it is often possible to get back into operation rapidly. If it is due to an unknown cause, it may be necessary to do detailed failure analysis--requiring extended downtime of the affected system.
- Astronauts safety--in the event of significant radiation, astronauts can move to shielded areas.

(4) Prediction of:

- Solar Proton Events (astronaut/airline flight safety). Goals: (a) reliable warnings (minimize false alarm rate) and (b) reliable forecast of "all clear" periods for EVA's.
- Prediction of geomagnetic storms for applications where effective mitigation is possible (e.g. electric power grid). Goals--reliable forecasts (storm is coming) and very reliable shorter term (~hour) warnings to minimize unnecessary mitigation by reducing capacity, etc. which can reduce system efficiency.
- Predictions of space environment for operation and utilization of space systems. Goals: (a) reliably forecast availability/accuracy/sensitivity of communication and navigation systems susceptible to space weather (e.g. ionospheric scintillations) and (b) enable optimization of systems and the allocation of resources during times of extreme space weather conditions.

In summary, LWS will characterize the space environment with the aim being to help spacecraft designers and operators, and address astronaut health and safety. LWS will produce the system knowledge to predict solar effects on climate, and solar/geospace effects on human systems in space and on the ground.

The approach to achieving our goals is to treat the Sun, heliosphere, and geospace as a system. The key to dealing with the problem as a system is to understand that physics-based models will be the "glue" that holds the system together. It is assumed that ultimately reliable and serviceable models combined with key observations of the SEC system will allow the prediction of what will happen--where and when. Model requirements will drive what observations are needed for boundary conditions and "truth" tests of the models.

The present approach to implementing a systems-based program is to define the management structure along scientific problem lines. The space environment research area includes the effects of solar variability on climate and global change as well as specification of radiation and density models. The space storms area includes the specification of the environment on a more real-time or nowcasting and event basis. Included as well is the ultimate goal of the LWS, the physical understanding of the end-to-end Sun-Earth system, enabling reliable predictive capability of storm effects. The program has the following elements: (1) a Space Weather Research Network of solar-terrestrial spacecraft; (2) a theory, modeling, and data analysis program; and (3) Space Environment Testbeds (SET) for flight testing radiation-hardened and radiation-tolerant systems in the Earth's space environment. Vital to the success of LWS and critical to the satisfaction of national needs is the development of partnerships with national and international agencies and industry.

Implementation of LWS will proceed in two phases. The first phase will include: (1) a geosynchronous spacecraft that will observe the Sun from its interior (via helioseismology techniques) to the outermost extensions of its atmosphere where solar activity produces the variable solar output of electromagnetic radiation, solar wind, and energetic particles, and (2) the Geospace Mission, a set of spacecraft

to understand geospace as a function of time and the effects of solar events and local instabilities on its evolution. The second phase will add a set of heliospheric spacecraft to determine the state of the solar wind and the propagation of events.

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-6 and Figure 3-NASA-7).
- 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

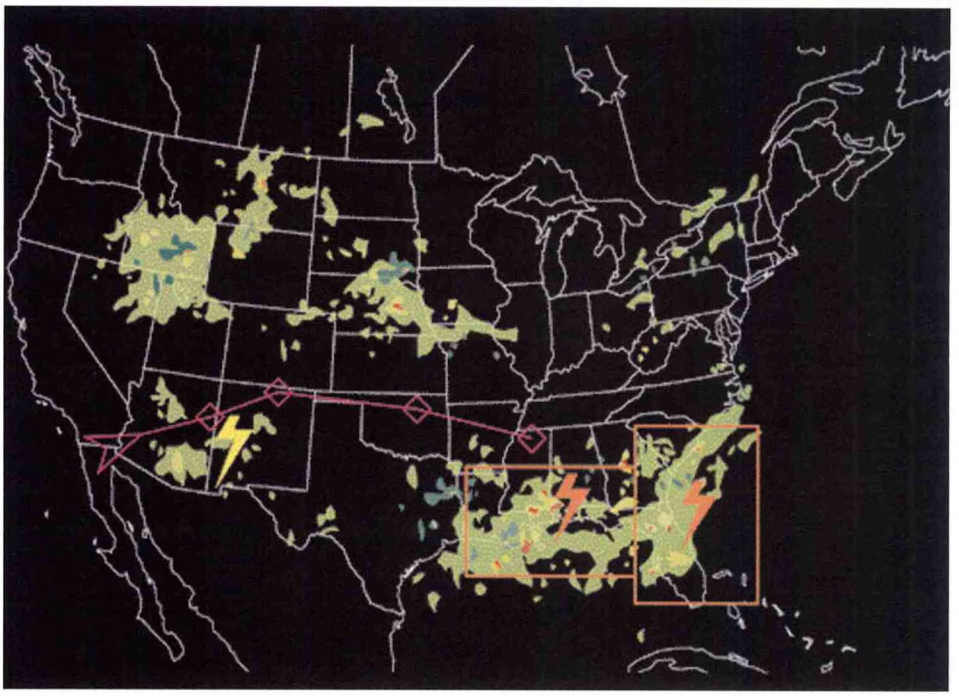


Figure 3-NASA-6. Cockpit display of national weather radar mosaic.

encounters. There is also work in ground based detection (Figure 3-NASA-8).

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 deicing 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:

- 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.

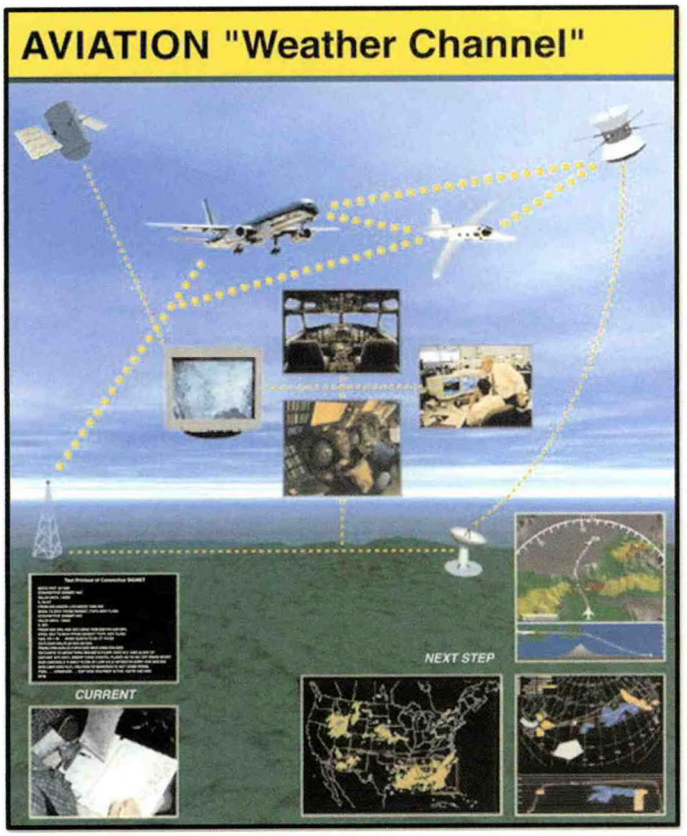


Figure 3-NASA-7. Communication and distribution channels for Aviation weather information.

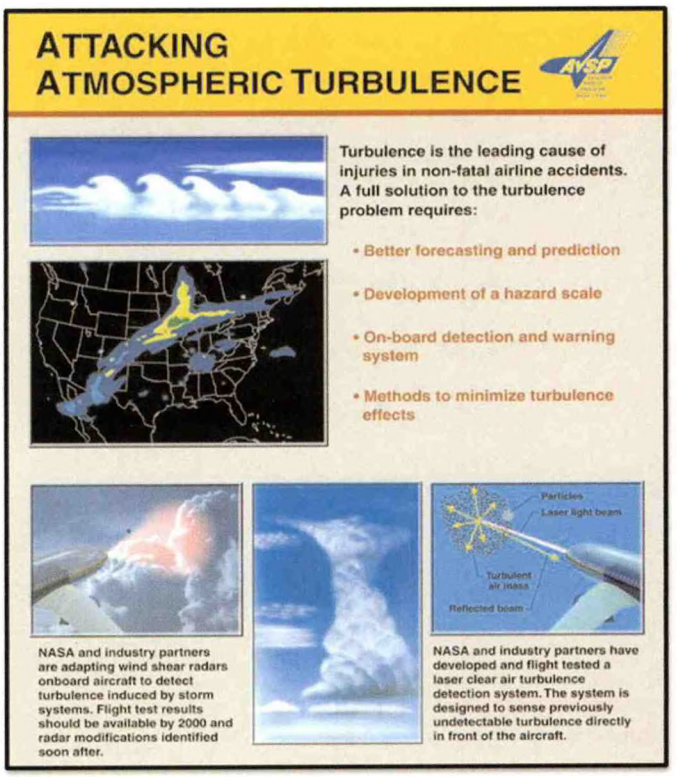


Figure 3-NASA-8. NASA's Aviation Safety Program plans to detect atmospheric turbulence through the use of advanced technologies.

• 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.

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 conduct reviews of nuclear facility siting, design, construction, and operation. These reviews include consideration of meteorological factors. The two offices also conduct rulemaking to establish regulatory requirements. The NRC Regional Offices assure that licensing conditions are followed by NRC licensees. Together with the NRC Incident Response Operations, they also carry out NRC responses to nuclear facility emergencies.

The Office of Nuclear Regulatory Research (RES) conducts research in various categories to identify potential safety issues, and to prepare the agency to regulate the use of new technology. RES 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.

Figure 3-NRC-1. NRC regulates the storage of spent fuel at nuclear plants. The photo shows a fuel cask being maneuvered in a cradle at the Hatch plant in Georgia.

At the present time, the NRC is a user of meteorological information, rather than performing research in this field. Meteorological data will be used to assess radiological impacts of routine airborne releases from facilities and to evaluate the impact of proposed changes in plant design or operation on unplanned releases. Information of this type is also important for developing scenarios of climatological impacts on the isolation of long-lived nuclear wastes. The NRC also maintains an interest in the transport and dispersion of airborne, hazardous, non-radioactive materials, and the effects of extreme meteorological events on the safe operation of nuclear facilities.

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 2001 was $13.9 million and this amount is expected to decrease slightly in FY 2002.

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-2001 shared budget was $14.0 million with NSF supplying $2.7 million. The total funding for FY 2002 is expected to increase slightly.

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 2001 USGCRP funding was $187.5 million and in FY 2002 is expected to be $187.5 million. The Division of Atmospheric Sciences USGCRP funding for FY 2001 was $44.0 million with FY 2002 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 2001 was $1.5 million and is expected to stay the same for FY 2002.

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, working groups, and joint action 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 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 2001 AND PLANS FOR FISCAL YEAR 2002

NATURAL DISASTER REDUCTION

55th Interdepartmental Hurricane Conference (IHC) (March 5-9, 2001). 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. The 55th IHC was held in Orlando, Florida. The theme for the conference was *Landfalling Hurricanes-A Major Challenge for Operations and Research in the 21st Century*. The conference was attended by over 210 people -- a new record, representing twelve federal agencies, the academic community, local emergency management, and the weather media. Special sessions were conducted on transitioning research to operations and the Hurricane Landfall component of the United States Weather Research Program (USWRP). The major outcome of the IHC was identification of the need for a sustainable, formalized approach to transition successful research results into the operational environment, which the OFCM will pursue through its Committee for Cooperative Research. In May, OFCM published the 39th edition of the *National Hurricane Operations Plan*, which details responsibilities of federal agencies; operations and procedures; products; aircraft, satellite, radar, and buoy data collection; and marine weather broadcasts.

National Hurricane Conference (April 9-13, 2001). OFCM sponsored a three-hour session attended by more than 200 individuals at the 2001 National Hurricane Conference with the theme *Toward a Safer America: Making the Nation More Resilient to Hurricanes*. The session included two distinguished panels which addressed managing the public's vulnerabilities and consequences through risk assessment and management, and improving hurricane preparedness and response through new communications technology and enhancing public outreach and education.

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 in the Tallahassee Florida area (northern Florida and southern Georgia) in mid-March 2001, and to examine flooding, ice jams, and levies in the area of the Red River near Grand Forks, North Dakota, in early April 2001. Aerial photographic support was provided by the Air Force's Civil Air Patrol (CAP). The CAP support, negotiated by the working group and documented in a memorandum of understanding, has proven to be both timely and very cost effective.

Severe Local Storms Operations. In May 2001, the OFCM-sponsored Joint Action Group for Severe Local Storms Operations published the *National Severe Local Storms Operations Plan*. The plan outlines the responsibilities of the various United States federal agencies that provide meteorological services in observing, forecasting, and warning of severe local storms. It also defines meteorological terms used by the agencies preparing severe local storms forecasts and warnings; identifies differing operational warning criteria and procedures; and discusses communications, observations, and some public release aspects of severe storms warnings.

TRANSITION ISSUES

The Federal Committee for Meteorological Services and Supporting Research (FCMSSR) met on November 14, 2000, in the Herbert C. Hoover Building, Washington,

District of Columbia, to focus on issues that were relevant to the transition team for the next administration. The meeting was very successful and was attended by thirteen of the FCMSSR agencies. A white paper identifying and describing transition issues was prepared subsequent to the meeting and provided to the agencies for use in interactions with the transition team. Areas and issues identified were: (1) The Next Step Beyond Modernization (fully implement observational program; continue evolution of National Weather Service (NWS) systems); (2) Climate Services (implement global climate ocean observing systems; upgrade national computational capabilities); (3) Comprehensive Strategy for Emergency Management (support FEMA's *Project Impact*; support the Global Disaster Information Network; communicate rainfall and flooding information better); (4) Landfalling Hurricanes (improve hurricane track and intensity forecasts; follow and report on hurricanes after landfall); (5) Transportation (enhance weather information dissemination for aviation; improve accuracy of convective forecasts for aviation; improve road weather information); and (6) Strategy for Atmospheric Information (develop a strategy for atmospheric information; improve communication of weather and climate information).

ANNUAL FEDERAL PLAN

OFCM prepared *The Federal Plan for Meteorological Services and Supporting Research -- Fiscal Year 2002*. The Federal Plan is Congressionally mandated and is a one-of-a-kind document which articulates the meteorological services provided and supporting research conducted by agencies of the federal government. The Federal Plan helps to reduce duplication among the agencies. It is a comprehensive publication that documents proposed programs for Fiscal Year 2002 and reviews agency programs in Fiscal Year 2001. The Plan demonstrates to the Congress and to the Executive Branch how the agencies work together to accomplish their missions in an effective and efficient manner.

WEATHER INFORMATION FOR SURFACE TRANSPORTATION

OFCM has continued its extensive involvement in the area of 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, *Preparing for the Future: Improved Weather Information for Decision-Makers* was held December 4-6, 2000, in Rockville, Maryland. The symposium was attended by more than 100 individuals who were a cross-section of the transportation and weather communities (federal, state, and city governments, urban and rural transportation agencies, professional and trade organizations, and government and commercial weather service providers). Eight overarching areas of concern were identified and five specific action items were highlighted as needing priority for continued progress. The bottom line is that improvements in surface transportation weather support will result in safer and more efficient operations by all users.

OFCM also made substantial progress in preparation of a document addressing meteorological requirements for the six core modes of surface transportation: roadway, railway, transit, waterway, pipeline, and airport ground operations. This activity has included formation of a joint action group to address meteorological requirements for surface transportation; questionnaires; surveys; WIST symposia conducted jointly with the Federal Highway Administration; meetings with railroad, pipeline, and emergency managers; and participation on panels concerning public-private partnerships in transportation and Intelligent Transportation Systems. The requirements document will be a culmination of intensive OFCM efforts in this area and is expected to be published in November 2001.

AVIATION WEATHER

OFCM completed its analysis of agency and industry programs/projects identified as meeting the needs and concerns contained in the January 1999 *National Aviation Weather Initiatives* document. A significant enabler in the process was the OFCM-sponsored July 2000 Aviation Weather User Forum. The forum provided an opportunity for open dialog between program managers as well as the users and providers of aviation weather information. The forum also played a significant role in completing the *National Aviation Weather Initiatives Tier 3 (Service Design)/Tier 4 (Budgets and Schedules) Baseline Report* which was issued in April 2001, a first-ever achievement for all government. The report was a major contribution toward establishing a baseline for ongoing and planned research and development for each initiative (requirements and products). The report will serve as a vehicle for transitioning research results into operations. Of the 86 initiatives, only ten have no agency identified as satisfying a particular need or concern. The next step will focus on key issues and actions identified during the Aviation Weather User Forum. One such issue is the need for improved aviation weather training and, in that regard, OFCM will take a leadership role in coordinating the establishment of a National Training Program. Another issue deals with establishing, validating, and prioritizing requirements. Now that we have established a baseline, the Joint Action Group for Aviation Weather will revisit the initiatives to determine if they continue to

represent the priorities for aviation safety and efficiency. Consideration will also be given as to how best to meet the requirements for the ten initiatives identified that are not now being addressed by agencies or industry. OFCM is also continuing efforts concerning volcanic ash and expects to publish *A National Framework for Volcanic Ash Hazards to Aviation during FY 2002*.

WIND CHILL TEMPERATURE INDEX

Under the leadership of OFCM's federal coordinating infrastructure, United States federal agencies, Canadian participants, and the academic research community have taken an important step towards improving the Wind Chill Temperature (WCT) Index. The new WCT Index will provide the citizens of the United States and Canada better protection of life and property. The current wind chill index attempts to measure the rate of heat loss by the human body as wind blows across it at different temperatures and speeds. The index was developed in the 1940s during an Antarctic expedition, and is now known to overestimate the effect of wind by at least ten degrees. This overestimate gives a false sense of security and people are sometimes not aware or prepared for the danger of severe winter weather. OFCM led the improvement effort by creating a Joint Action Group for Temperature Indices within its federal coordinating infrastructure, and this Joint Action Group pulled together the various United States, Canadian, and academic entities to develop the new WCT Index based on 21st Century science. Funding for the development of the new WCT Index was provided by OFCM, the United States Army's Cold Region Research and Engineering Laboratory, and the Defence Research and Development Canada. NOAA's NWS, the United States Air Force, and the Meteorological Service of Canada will implement the new WCT Index during the winter season of 2001-2002. This new WCT Index will be a substantial improvement over the current practice and will be based on a human face model, use wind speed calculated at the average height of an adult's face, incorporate modern heat transfer theory, lower the walking speed threshold used in calm wind situations, and use a consistent standard for skin tissue resistance. Later refinements will include adjustments for solar radiation for a variety of conditions.

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 (NSWP), 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 *NSWP Strategic Plan* and *Implementation Plans* provide, respectively, broad guidance and a detailed roadmap for the Program. The Committee for Space Weather (CSW) recently established the Community Coordinated Modeling Center (CCMC), with a mission to prepare the next generation of space weather models for transition to operations through the operational centers' rapid prototyping centers. During FY 2001, the fledgling CCMC transferred its first model to the Department of Commerce's Space Environment Center (SEC). The magnetohydrodynamic version of the Magnetospheric Specification Model will significantly improve the SEC's ability to predict the future state of the magnetosphere based on solar wind inputs. Nearing completion is work on coupling this model with a radiation belt model. During 2002, the CCMC will focus on ionospheric and heliospheric models and coupling ionospheric and magnetospheric models. In addition, the highly successful competition for space weather research grants, sponsored and administered by the National Science Foundation (NSF), will continue in 2002 with a modest increase in funding.

STRATEGY FOR PROVIDING ATMOSPHERIC INFORMATION

OFCM is planning a forum to respond to the agency priorities and to address Leadership and Management Recommendation 1 of the National Research Council/National Academy of Sciences Board on Atmospheric Sciences and Climate (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.*" The Federal Coordinator began this effort by drafting a concept development paper which was provided to thirty agencies and individuals for feedback. The objective was defined to "Plan and promote the effective and efficient availability and distribution of atmospheric information that meets the requirements of all agencies (operational and research)." Major issues were identified to include: roles and responsibilities of the public and private sectors;

availability of data (data receipt and distribution) and archival capabilities; health of the meteorological infrastructure; international commitments for free and open data exchange; and role of academic research, both basic and applied. The methodology would examine major issues in climate, natural hazards, technological hazards, urban meteorology and air quality, ecosystem management and agriculture, and aviation and surface transportation. The forum will be conducted in early December 2001.

UNITED STATES WEATHER RESEARCH PROGRAM

The USWRP mission is to accelerate forecast improvements of high-impact weather and facilitate full use of advanced weather information. The USWRP's vision is to mitigate the effects of weather-induced disasters; reduce the costs associated with routinely disruptive weather; create opportunities for increased productivity through better weather information; and assist the military in the accomplishment of its mission. The current USWRP team includes NOAA as the lead agency, NSF, National Aeronautics and Space Administration, and the United States Navy. The Federal Coordinator has taken steps to contact additional agencies to broaden federal participation in the USWRP in accordance with an action from the Interdepartmental Committee for Meteorological Services and Supporting Research, direction from the Chairman of the Federal Committee for Meteorological Services and Supporting Research, and also recommendation from the National Academy of Sciences/National Research Council Board on Atmospheric Sciences and Climate (BASC). OFCM hosted meetings on expanded agency participation in the USWRP on May 11 and August 24, 2001. The additional agencies included Federal Aviation Administration, FHWA, USAF, DOE, USDA, and FEMA. These meetings have led to more interaction directly between the leadership of the USWRP and interested agencies to discuss, in more detail, agency specific needs which may be benefited by the program. It is expected that several additional federal participants will join the USWRP and that the USWRP priorities will be expanded to address their needs.

COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

OFCM and the Committee on Environment and Natural Resources (CENR) Subcommittee on Natural Disaster Reduction (SNDR) cosponsored the Forum on Risk Management and Assessments of Natural Hazards February 5-6, 2001. The forum theme was *Toward a Safer America: Building Natural Hazard Resistant Communities through Risk Management and Assessments*. It was attended by an unprecedented cross-section of more than 120 weather, natural disaster and risk management professionals, and academia. Consensus was reached to proceed with a national natural hazard assessment and to develop an action plan which would deal with the assessment in manageable pieces. It was also agreed to integrate efforts with the Congressional Natural Hazards Caucus; develop improved partnerships between users and developers; standardize terminology, methodology, and approach within risk assessment and management; compile available risk assessment tools and models; and improve public outreach, education, and training.

AMERICAN METEOROLOGICAL SOCIETY

During FY 2001, OFCM joined nine 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 2002. OFCM also supports American Meteorological Society endeavors by participating in AMS conferences and workshops and other environmental science education and outreach programs.

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 2001*
- *National Hurricane Operations Plan*
- *55th Interdepartmental Hurricane Conference (Minutes)*
- *Proceedings for the Symposium Weather Information for Surface Transportation, Preparing for the Future: Improved Weather Information for Decision-Makers*
- *Proceedings of the Forum on Risk Management and Assessments of Natural Hazards*
- *National Severe Local Storms Operations Plan*
- *National Aviation Weather Initiatives Tier 3 (Service Design)/Tier 4 (Budgets and Schedules) Baseline Report*

The following documents are planned for publication during FY 2002:

- *The Federal Plan for Meteorological Services and Supporting Research -- Fiscal Year 2002*
- *National Hurricane Operations Plan*
- *56th Interdepartmental Hurricane Conference (Minutes)*

- *Weather Information for Surface Transportation (WIST) Requirements*
- *Proceedings for Workshop on BASC 21st Century Report Recommendation -- A Strategy for Atmospheric Information*
- *National Plan for Post-Storm Data Acquisition*
- *A National Framework for Volcanic Ash Hazards to Aviation*

During FY 2001, 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 2002.

Table A.1 Current OFCM Publications

Publication Title	Date	Number
Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 2001	*June 2000*	*FCM-P1-2000*
National Plan for Space Environment Services and Supporting Research: 1993-1997	August 1993	FCM-P10-1993
National Severe Local Storms Operations Plan	*May 2001*	*FCM-P11-2001*
National Hurricane Operations Plan	*May 2001*	*FCM-P12-2001*
National Winter Storms Operations Plan	*November 2000*	*FCM-P13-2000*
Federal Plan for Cooperative Support and Backup Among Operational Processing Centers	*May 1996*	*FCM-P14-1996*
National Plan for Stratospheric Monitoring, 1988-1997	July 1989	FCM-P17-1989
National Aircraft Icing Technology Plan	April 1986	FCM-P20-1986
National Plan to Improve Aircraft Icing Forecasts	July 1986	FCM-P21-1986
Federal Plan for the Coordination of Automated Weather Information System Programs	May 1988	FCM-P23-1988
Federal Plan for Meteorological Information Management	July 1991	FCM-P24-1991
National Plan for Tropical Cyclone Research and Reconnaissance (1997-2002)	*January 1997*	*FCM-P25-1997*
National Aviation Weather Program Plan	September 1992	FCM-P27-1992
National Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS) Operations Plan	August 1997	FCM-P28-1997
Federal Plan for Marine Environmental Data, Services, and Supporting Research	June 1996	FCM-P29-1996
The National Space Weather Program: Strategic Plan	*August 1995*	*FCM-P30-1995*
The National Space Weather Program: Implementation Plan - 2nd Edition	*July 2000*	*FCM-P31-2000*
National Aviation Weather Strategic Plan	*April 1997*	*FCM-P32-1997*
National Aviation Weather Initiatives	*February 1999*	*FCM-P34-1999*
National Aviation Weather Initiatives, Final Baseline Tier 3 and 4 Report	*April 2000*	
Federal Meteorological Handbook No. 1 - Surface Weather Observations and Reports	*December 1995*	*FCM-H1-1995*
Federal Meteorological Handbook No. 2 - Surface Synoptic Codes Surface Synoptic Code Tables (Update)	December 1988 July 1990	FCM-H2-1988 FCM-T1-1990

Table A.1 Current OFCM Publications (cont.)

Publication Title	Date	Number
Federal Meteorological Handbook No. 3 - Rawinsonde and Pibal Observations	*May 1997*	*FCM-H3-1997*
Federal Meteorological Handbook No. 10 - Meteorological Rocket Observations	December 1988	FCM-H10-1988
Federal Meteorological Handbook No. 11 - Doppler Radar Meteorological Observations		
Part A - System Concepts, Responsibilities and Procedures	June 1991	FCM-H11A-1991
Part B - Doppler Radar Theory and Meteorology	June 1990	FCM-H11B-1990
Part C - WSR-88D Products and Algorithms	February 1991	FCM-H11C-1991
Part D - WSR-88D Unit Description and Operational Analysis	April 1992	FCM-H11D-1992
Federal Meteorological Handbook No. 12 - United States Meteorological Codes and Coding Practices	*December 1998*	*FCM-H12-1998*
Directory of Atmospheric Transport and Diffusion Consequence Assessment Models	*March 1999*	*FCM-I3-1999*
Federal Directory of Mobile Meteorological Equipment and Capabilities	*December 1995*	*FCM-I5-1995*
A Guide to WMO Code Form FM 94 BUFR	*March 1995*	*FCM-I6-1995*
Tropical Cyclone Studies	December 1988	FCM-R11-1988
Tropical Cyclone Studies Supplement	August 1989	FCM-R11-1988S
Interdepartmental Meteorological Data Exchange System Report, IMDES	*August 1998*	*FCM-R12-1998*
Federal Meteorological Requirements 2000	October 1990	FCM-R13-1990
U.S. Wind Profiler: A Review	*March 1998*	*FCM-R14-1998*
Standard Formats for Weather Data Exchange Among Automated Weather Information Systems	November 1994	FCM-S2-1994
Standard Telecommunication Procedures for Weather Data Exchange (under revision)	October 1991	FCM-S3-1991
Federal Standard for Siting Meteorological Sensors at Airports	*August 1994*	*FCM-S4-1994*
54th Interdepartmental Hurricane Conference (Minutes)	May 2000	
Proceedings of the Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community	*June 2000*	
Proceedings of the Aviation Weather User Forum--Aviation Weather: Opportunities for Implementation	*July 2000*	
Proceedings for the Weather Information for Surface Transportation: Delivering Improved Safety and Efficiency for Tomorrow Symposium	*February 2000*	
Proceedings of the Symposium on the Weather Information for Surface Transportation -- Preparing for the Future: Improved Weather Information for Decision Makers	*March 2001*	
Proceedings of the Forum on Risk Management and Assessment of Natural Hazards	*July 2001*	

Italics = publication available online at *www.ofcm.gov*

APPENDIX B

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 are to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and climatic change. The ability of the United States and other nations to use their existing scientific capability to understand the climate and to increase their weather predicting skills is limited by the lack of global weather data. Available weather data are inadequately observed over 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 operational 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 primary operational NOAA polar-orbiting satellites are NOAA-16 (launched in an afternoon orbit in September 2000) and NOAA-15 (launched in a morning orbit in May 1998). The current primary operational DMSP polar-orbiting satellites are F-15 (launched in December 1999) and F-14 (launched in April 1997). Also, China is operating its first generation FY-1C satellite launched in May 1999 in sun-synchronous morning orbit.

Preparations continue with the Europeans for their assumption of NOAA's morning polar orbit mission starting with the launch of Metop-1 in 2005. This complements United States plans to merge NOAA's POES with the DMSP to form an integrated system called NPOESS (National Polar-orbiting Operational Environmental Satellite) System that is expected to fly at the end of this decade. NOAA, DOD, and NASA are working together to implement NPOESS in the context of 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 acquisition, launch, and system integration. NOAA will facilitate the development and incorporation of new, cost-effective technologies to enhance the NPOESS capabilities.

Operational geostationary weather satellites are currently operated by Japan, India, Russia, the United States, and the European Organization for the Exploitation of (EUMETSAT). Japan's Geostationary Meteorological Satellite (GMS) is positioned at 140 degrees East, India's Indian National Satellites (INSAT) are at 74 degrees East and 93.5 degrees East, Russia's GOMS/Elektro #1 satellite is at 76 degrees East (operational from June 1996 until September 1998, currently in stand-by), and EUMETSAT's METEOSATs are at 0 degrees and 63 degrees East. The United States operates two Geostationary Operational Environmental Satellites (GOES) - at 75 degrees West and 135 degrees West. GOES-8, launched in April 1994, is operational at 75 degrees West and GOES-10, launched in April 1997, is operational

at 135 degrees West. China's also launched its first pre-operational geostationary environmental satellite FY2A on June 10, 1997, and its second FY2B on June 25, 2000. FY2B is located at 105 degrees East and FY2A was moved to the backup position at 85.6 degrees East.

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 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.

The ASDAR program has continued to provide valuable observations over data sparse regions of South America, the central and southern Atlantic Ocean, Africa, the Indian Ocean, Asia, and Eastern Europe. Much of this area is otherwise not covered by any *in-situ* upper air observations. However, this situation is expected to change in the near future as many of the existing ASDAR equipped aircraft will be converted or replaced by other aircraft fitted with conventional AMDAR systems. The program peaked early in 1998 with 21 operational systems. However, since then there has been a substantial reduction in the size of the ASDAR program. This was accomplished in 2 phases with the first 5 British Airways 747 aircraft decommissioned between October 1998 and August 1999 and the second and final 5 aircraft between January and June 2000. These same aircraft have been fitted with AMDAR software along with 45 other aircraft in the B747-400 fleet. KLM decommissioned the first of its 3 operational units in April 2001.

Although the program is in decline, several units have a priority and should be kept operating for a few more years as they will still form the main source of aircraft observations in critical data void areas. These include units on aircraft from Air Mauritius (2), KLM (2) and Aerolineas Argentinas (2). The South African units (2) will eventually be replaced by AMDAR systems as will be the 2 units operated by Saudi Arabia, but not for at least another year.

During the second quarter of 2001, data availability indicates 93.3 percent of observations were received within 60 minutes and 99.5 percent within 115 minutes. An average of 994 reports per day were received. Concerns regarding data quality of some aircraft, particularly in temperature, are being addressed.

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 80,000 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 six airlines: Delta, Northwest, United, United Parcel Service (UPS), American Airlines and Federal Express (FedEx).

Two additional MDCRS reporting elements continue under development: water vapor and turbulence. A new water vapor sensor, using diode laser technology, is being tested. This new sensor will replace the current version being flown on 30 UPS B-757 aircraft as part of a demonstration program. Ultimately, this new technology is hoped to be flown operationally on commercial aircraft. A new turbulence algorithm, developed by the National Center for Atmospheric Research (NCAR) derives an objective, aircraft independent measure of turbulence (eddy dissipation rate-EDR) from aircraft vertical acceleration. The EDR is included as part of the MDCRS data stream. The algorithm is currently installed on 90 United Airlines aircraft and will be installed on over 400 United, American, Delta, and Northwest aircraft by FY 2003.

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) established 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. Several countries have developed AMDAR programs of their own, focused on obtaining aircraft data over data sparse areas, including South Africa, Hong Kong, Russia, Saudi Arabia, and the Caribbean.

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.

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.

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 have been defined to provide basic global 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 collection and archival, and additional quality control, storage, and retrieval, to include cataloging observational data and processed information for operational and special applications and for research.

WMCs are located in Melbourne, Moscow, and Washington; they provide 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; Singapore; 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; Miami, Florida. and Honolulu, Hawaii, 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, and act as back-up for one another.

The gradual implementation of the final phase of the WAFS has begun. 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 collection of meteorological data from upper-air and surface-observing sites.
- Continued implementation of satellite direct-readout stations that are compatible with polar-orbiting satellites and the weather facsimile (WEFAX) 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.

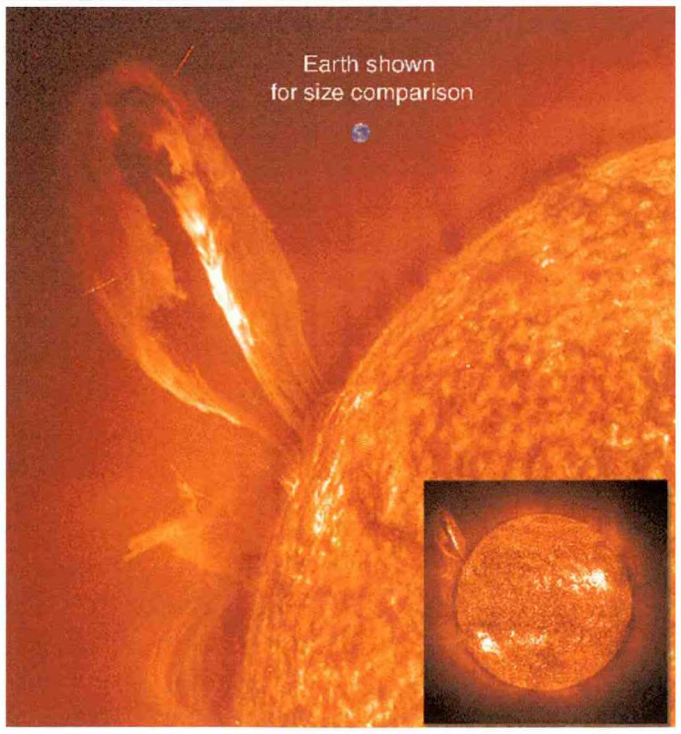
Over the past few years, the Mexican Meteorological Service has undergone some modernization which included upgrading upper-air observation systems and installing Doppler weather radars. This cooperative agreement will facilitate the exchange of data and information to the benefit of both countries.

National Space Weather Program

The National Space Weather Program (NSWP) was initiated in 1994, and the goals of the program were articulated in the NSWP Strategic Plan, published in 1995. The overarching goal of the program is to achieve, within the next ten years, an interagency system to provide timely, accurate, and reliable space environment observations, specifications, and forecasts. A detailed Implementation Plan was published in 1997 and updated in 2000. The NSWP focuses on four elements-research, observations, models, and education-which, taken together, support improvement in the ability to specify and forecast space weather in support of a variety of customers. This customer base includes operators and/or users of communications systems, satellites, power grids, navigation systems, and manned spaceflight systems.

The NSWP is led through the Federal coordinating infrastructure of the Office of the Federal Coordinator for Meteorology (OFCM). OFCM's multi-agency National Space Weather Program Council (NWSPC) sets policy and provides oversight and direction to the program. The Committee for Space Weather (CSW) is aligned under the Program Council and implements policy and provides management of the NSWP.

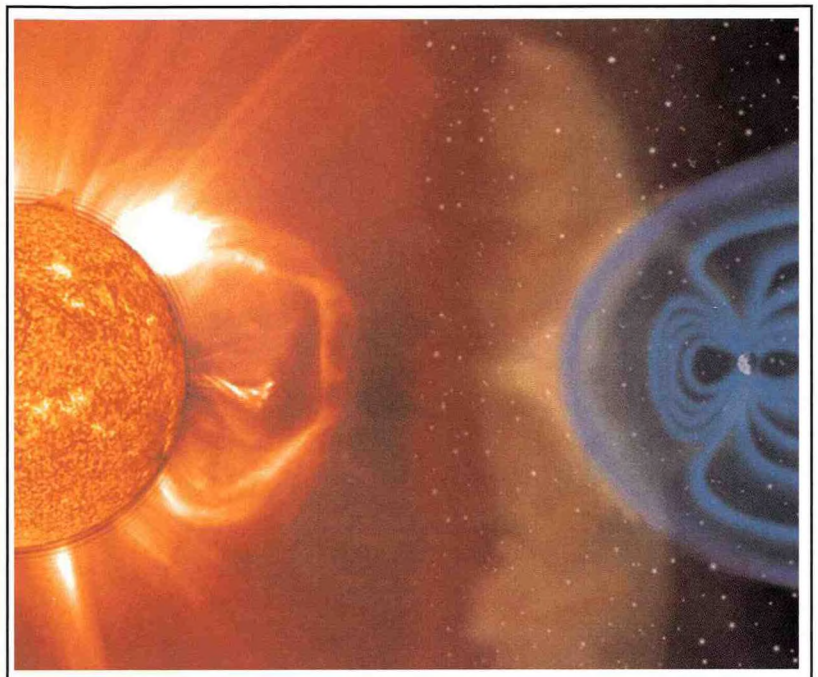
Detailed information on OFCM and agency NSWP involvement appears in various sections of this plan. The reader is invited to review the following sections to learn more about current activities related to the program:



Solar Prominence on Sun's Limb

Large, eruptive prominence in He II at 304Å, with an image of the Earth added for size comparison. This prominence from 24 July 1999 is particularly large and looping, extending over 35 Earths out from the Sun. Erupting prominences (when Earthward directed) can affect communications, navigation systems, even power grids, while also producing auroras visible in the night skies.

SPACE WEATHER



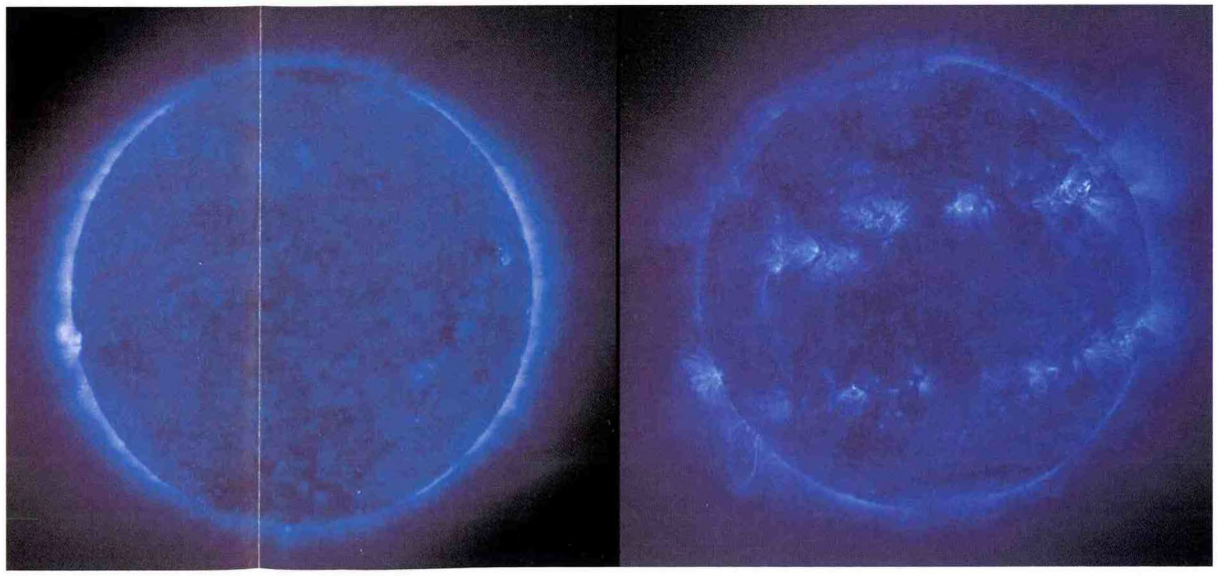
Coronal Mass Ejection (CME) blast and subsequent impact at Earth

This illustration shows a CME blasting off the Sun's surface. The left portion is composed of an extreme ultra-violet (EUV) image superimposed on SOHO's coronagraph. Two to four days later, the CME cloud is shown striking and beginning to be mostly deflected around the Earth's magnetosphere. The blue paths emanating from the Earth's poles represent some of its magnetic field lines. The magnetic cloud of plasma can extend to 30 million miles wide by the time it reaches earth. These storms, which occur frequently, can disrupt communications and navigational equipment, damage satellites, and even cause blackouts. (Objects in the illustration are not drawn to scale.)

All solar images from Solar Heliospheric Observatory (SOHO)

Illustrating Solar Variability

A comparison of two images almost two years apart illustrates how the level of solar activity has increased significantly. The Sun attained its expected sunspot maximum in the year 2000. These images are captured using Fe IX-X 171 Å emission showing the solar corona at a temperature of about 1.3 million K. Many more sunspots, solar flares, and coronal mass ejections occur during the solar maximum. The numerous active regions and the number/size of magnetic loops in the recent image shows the increase.



APPENDIX D
PREVIOUS FEATURE ARTICLES

2000	FY 2001	The Legacy of Hurricane Floyd--Inland Flooding and a Massive Evacuation	Mr. Robert Dumont, OFCM
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 E
ACRONYMS AND ABBREVIATIONS

4DWX	Four Dimensional Weather (Army)
AA	Active Army
AASHTO	American Association of State Highway and Transportation Officials (FHWA)
ABCS	Army Battle Command System (Army)
ABFM	Airborne Field Mill (NASA)
ABL	Airborne Laser (AF)
ABLE	Atmospheric Boundary Layer Experiment (DOE)
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)
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
AFFFSA	Air Force Flight Standards Agency
AFJI	Air Force Joint Instruction
AFOSR	Air Force Special Office of Scientific Research
AFRL	Air Force Research Laboratory
AFSOC	Air Force Special Operations Command
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 Services (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
ANL	Argonne National Laboratory (DOE)
AOC	Aircraft Operations Center (NOAA)
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA/ERL)
AOR	Area of Responsibility (DOD)
AOT	Aerosol Optical Thickness (NOAA/NESDIS)
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)
ARSPACE	Army Space Command
ARSR	Air Route Surveillance Radar (FAA)
ARSST	Army Space Support Team
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)
ASOG	Air Support Operations Group (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	Advanced Warfighting Experiments (Army)
AWIPS	Advanced Weather Interactive Processing Systems (NOAA)
AWN	Automated Weather Network (DOD)
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)
BER	Biological and Environmental Research (DOE)
BFA	Battlefield Functional Areas (Army)
BLM	Bureau of Land Management (DOI)
BMDO	Ballistic Missile Defense Office (AF)
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)

CART	Clouds and Radiation TEstbed (DOE)
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
CCMC	Community Coordinated Modeling Center (AF)
CCMS	Committee on the Challenge of Modern Society (EPA)
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/NESDIS)
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)
CLASS	Comprehensive Large Array-Data Stewardship System (NOAA/NESDIS)
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 (DOD)
CONUSA	Continental United States Armies (Army)
COPC	Committee for Operational Processing Centers (OFCM)
COOP	Cooperative Observer Program (NOAA/NWS)
CORMS	Continuous Real-time Monitoring System (NOAA/NOS)
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate (AF)
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)
CSD	Climate Services Division (NOAA/NWS)
CSEPP	Chemical Stockpile Emergency Preparedness Program (DOE)
CSRA	Central Savannah River Area (DOE)
CSREES	Cooperative State Research, Education, and Extension Service (USDA)
CSSM	Cloud Scene Simulation Model (AF)
CSW	Committee for Space Weather (OFCM)
CTA	Common Table of Allowances (Army)
CTBT	Comprehensive Test Ban Treaty (DOE)
CTWFC	CINC Target Weather Forecast Center (AF)
CWF	Combat Weather Flight (AF)
CWS	Combat Weather Squadron (AF)
CWSU	Center Weather Service Unit (FAA)
CWT	Combat Weather Team (AF)

CXD	Combined X-ray Dosimeter (DOE)
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)
DGPS	Differential Global Positioning System (USGS)
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)
DREN	Defense Research and Engineering Network (AF)
DRGS	Direct readout ground stations (DOI)
DRWP	Doppler Radar Wind Profiler (NASA)
DTC	Developmental Test Command (Army)
DTSS	Digital Topographic Support System (Army)
DUAT	Direct User Access Terminal (FAA)
DURIP	Defense University Research Instrumentation Program (Army)
DWSW	Deployable Weather Satellite Workstation (Army)
EAC	Echelon Above Corps (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)
ELV	Expendable Launch Vehicle (NASA)
EMC	Environmental Modeling Center (NOAA/NCEP)
ENSO	El Niño-Southern Oscillation
EO	Electro-optical
	Earth Observation (NASA)
EOC	Emergency Operations Center
	Environmental Operations Center (DOE)
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)
ESIP	Earth Science Information Partners (NASA)

ESP	Energy Spectrometer for Particles (DOE)
	Ensemble Streamflow Prediction (NWS)
ESS	Environmental Sensor Station (FHWA)
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 Area Limited Observing Program (AF)
FAS	Foreign Agricultural Service (USDA)
FBA	Fire Behavior Analysts (DOI)
FCCC	Framework Convention on Climate Change (DOS)
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FCS	Future Combat System (Army)
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)
FIRST	FAA Icing Remost Sensor Testbed (NOAA/OAR)
FIS	Flight Information System (FAA)
FLENUMMETOCCEN	Fleet Numerical 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
FOV	Field of vision
FRA	Federal Railroad Administration
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
FRWS	Fire RAWS (DOI)
FS-21	Forecasting System 21st Century
FS	Forest Service (USDA)
FSA	Farm Services Agency (USDA)
FSL	Forecast Systems Laboratory (NOAA/ERL)
FTA	Federal Transit Administration
FTE	Full-time Equivalent
FTP	File Transfer Protocol
FU	Forecast Unit
FY	fiscal year
G-IV	Gulfstream IV (NOAA)
GAC	Global Area Coverage
GACC	Geographic Areas and Coordination Center (DOI)
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
GDPS	Global Data Processing System (WWP)
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 (NOAA/NESDIS)
GOES	Geostationary Operational Environmental Satellite (NOAA)
GOOS	Global Ocean Observing System
GOS	Global Observing System (WWP)
GOSSP	Global Observing Systems Space Panel (NOAA/NESDIS)
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.)
GRIDS	Ground-based Remote Icing Detection System (NOAA/OAR)
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 regional broadcast (DOD)
HIGRAD	High Resolution and Strong Gradient
HIRS/3	High Resolution Infrared Radiation Sounder (NOAA/NESDIS)
HMI	Hydrologic Modeling Inventory (DOI)
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
HPCMO	High Performance Computing Modernization Office (AF)
HRAP	Hydrologic Rainfall Analysis Project (DOI)
HRD	Hurricane Research Division (NOAA/ERL)
HRPT	High Resolution Picture Transmission (NOAA/NESDIS)
HSA	Hydrologic Service Area (NOAA/NWS)
HSM	Heat Stress Monitor (Army)
HUD	Head-up display (NASA)
IAMS	Initial Attack Management System (DOI)
IAS	International Airspace System (NOAA/NWS)
IAV	Interim Armored Vehicle (Army)

IBCT	Interim Brigade Combat Teams (Army)
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)
IPB	Intelligence Preparation of the Battlefield (Army)
IPCC	Intergovernmental Panel on Climate Change (WWP/DOS)
IPEX	Intermountain Precipitation Experiment (NOAA/OAR)
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 (NOAA/NESDIS)
ISES	International Space Environment Service (NOAA/OAR)
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)
JAAWIN	Joint Air Force-Army Weather Information Network (AF)
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)
JSCP	Joint Strategic Capabilities Plan (Army)
JTWC	Joint Typhoon Warning Center (AF/Navy)
JWIS	Joint Weather Impacts System (AF)
KM	Kilometer
KMR	Kwajalein Missile Range (Army)
KSC	Kennedy Space Center
KVERT	Kamchatka Volcanic Eruption Response Team (DOI)

LAAS	Local Area Augmentation System (FAA)
LAC	Local Area Coverage
LAN	local area network
LANL	Los Alamos National Library (DOE)
LAPS	Local Analysis and Prediction System (NOAA/FSL)
LDAR	Lightning Detection and Ranging (NASA)
LDIS	Local Data Integration System (NASA)
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)
LSM	Land Surface Model (AF)
LWS	Living With A Star (NASA)
MACOM	Major Army Command
MAGTF	Marine Air Ground Task Force
MAIS	Military Aircrew Information System (AF)
MAJCOM	Major Command (AF)
MAW	Marine Aircraft Wing
MB	Millibars
MC	Meteorological Codes
MCAF	Marine Corps Air Facilities
MCAS	Marine Corps Air Station
MCD	Mesoscale Discussions (NOAA/NWS)
MCO	Maintenance and Construction Operations (FHWA)
MCS	Mesoscale Convective System (NOAA/OAR)
MDCRS	Meteorological Data Communications and Reporting System (WWP)
MDS	Meteorological Distribution System (Army)
MDSS	Maintenance Decision Support System (FHWA)
MeaPRS	MCS Electrification and Polarimetric Radar Study (NOAA/OAR)
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)
MHS	Microwave Humidity Sounder (NOAA/NESDIS)
MIMS	Multimedia Integrated Modeling System (EPA)
MISR	Multi-Angle Imaging Spectroradiometer (NASA)
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)
MPA	Magnetospheric Plasma Analyzer (DOE)
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)
MWO	Meteorological Watch Office (NOAA/NWS)
MWSS	Marine Wing Support Squadron
NADIN	National Airspace Data Interchange Network (FAA)
NAF	Numbered Air Force
NAMIS	NATO Automated Meteorological Information System (DOD)
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 for Tropospheric Ozone (EPA)
NAS	National Airspace System (FAA)
	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan (NASA)
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
NCA	National Command Authority (DOD)
NCAR	National Centers 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)
NIMA	National Imaging and Mapping Agency (DOD)
NIPRNET	Non-secure Internet Protocol Network (DOD)
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)
NNSA	National Nuclear Security Administration (DOE)
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 Airmen (FAA)
NOWS	NVG Operations Weather Software (AF)
NPN	NOAA Profiler Network (NOAA/OAR)
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)
NRVR	New Generation Runway Visual Range (FAA)
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)
NTIS	Naational Technical Information Service
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)
OCWWS	Office of Climate, Water, and Weather Services (NOAA/NWS)
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 II
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)

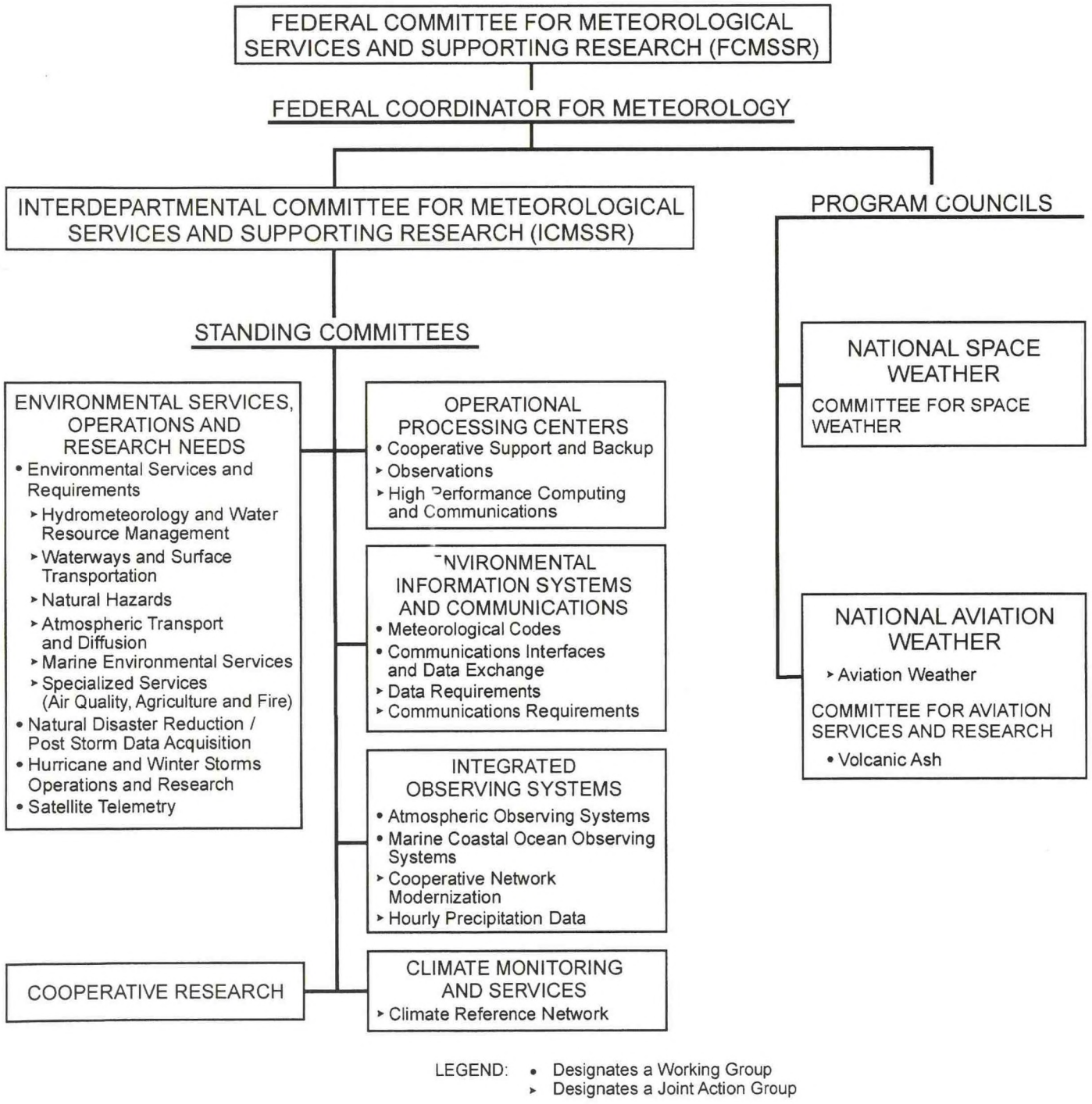
ORD	Operational Requirements Documents (DOD)
ORISE	Oak Ridge Institute for Science and Education (DOE)
ORR	Oak Ridge Reservation (DOE)
ORNL	Oak Ridge National Laboratory (DOE)
ORO	Oak Ridge Operations (DOE)
OS-21	Observing System 21st Century (AF)
OSDPD	Office of Satellite Data Processing and Distribution (NOAA/NESDIS)
OSEI	Operational Significant Event Imagery (NOAA/NESDIS)
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)
PAA	Precipitation Accumulation Algorithm (DOI)
PAC	Procurement, Acquisition, and Construction (NOAA/NWS)
PACS	Polar Acquisition and Control Subsystem (NOAA/NESDIS)
PASOS	Portable Automated Observing System (AF)
PBL	Planetary Boundary Layer (DOE)
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
PICASSO-CENA	Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations-Climatologie Etendue des Nuages et des Aerosols (NASA)
PIPS	Polar Ice Predication System (NOAA/NESDIS)
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&A	Research and Analysis
R&D	Research and Development
RAFC	Regional Area Forecast Center (WWP)
RAMS	Regional Atmopsheric Modeling System (DOE)
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)
RCC	Regional Climate Center (NOAA/NESDIS)

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)
ROC	Radar Operations Center (NOAA/NWS)
RPC	Rapid Prototype Center (NOAA/SEC)
RSA	Range Standardization and Automation (NASA)
RSMC	Regional/Specialized Meteorological Centers (WWP)
RTH	Regional Telecommunications Hub (WWP)
RTNEPH	Real-time Nephanalysis (AF)
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)
SAMS	Stochastic Analysis, Modeling, And Simulation (DOI)
SAP	Special Access Program
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)
SCI	Sensitive Compartmented Information (DOD)
SCINDA	Scintillation Network Decision Aid (AF)
SDHS	Satellite Data Handling System (AF)
SeaWiFS	Sea-viewing Wide Field Scanner (NASA)
SEC	Space Environmental Center (NOAA/NCEP)
	Sun Earth Connection (NASA)
SEM	Space Environment Monitor (NOAA)
SEMSIM	Southeastern Michigan Snow and Ice Management (FHWA)
SET	Space Environment Testbed (NASA)
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)
SMG	Spaceflight Meteorology Group (NASA)
SMOOS	Shipboard Meteorological and Oceanographic Observing Sensor (Navy)
SNDR	Subcommittee on Natural Disaster Reduction
SNL	Sandia National Laboratory (DOE)
SNODEP	Snow depth (AF)
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)
SOPA	Synchronous Orbit Plasma Analyzer (DOE)
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)
SRTM	Shuttle Radar Topography Mission (NASA)
SSOB	Special Support Operations Branch (DOD)

SSM/I	Special Sensor Microwave/Imager (NOAA/NESDIS)
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
STS	Special Tactics Squadron (AF)
STT	Small Tactical Terminal (AF)
STWDSR	Surface Transportation Weather Decision Support Requirements (FHWA)
SURFRAD	Surface Radiation (DOE)
SWA	Southwest Asia (DOD)
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)
	Space Weather Operations (NOAA/OAR)
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)
TCP	Transformation Campaign Plan (Army)
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)
	Total Electron Content (DOE)
TED	Total Energy 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)
TIMEX	Thunderstorm Initiation Mobile Experiment (NOAA/OAR)
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)
TOPEX	Topography Experiment (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)
UnESS	University Earth System Science (NASA)
UPOS	University Partnering for Operational Support (AF)
USA	U.S. Army
USAES	U.S. Army Engineer School
USAF	U.S. Air Force
USAFE	U.S. Air Forces in Europe
USAFAS	U.S. Army Field Artillery School
USAIC&FH	U.S. Army Intelligence Center and Fort Huachuca
USAKA	U.S. Army Kwajalein Atoll
USAR	U.S. Army Reserve
USARC	U.S. Army Reserve Command
USAREUR	U.S. Army Europe
USARIEM	U.S. Army Research Institute of Environmental Medicine
USARJ	U.S. Army Japan
USARPAC	U.S. Army Pacific
USASMDC	U.S. Army Space and Missile Defense Command
USASOC	U.S. Army Special Operations Command
USCENTCOM	U.S. Central 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
VAAC	Volcanic Ash Advisory Center (NOAA/NESDIS)
VAS	VISSR Atmospheric Sounder
VCL	Vegetation Canopy LIDAR (NASA)
VCP	Voluntary Cooperation Program (WWP)
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)
WAAS	Wide Area Augmentation System (FAA)
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)
WARSMP	Watershed and River System Management Program (DOI)
WCT	Wind Chill Temperature (OFCM)
WEFAX	Weather Facsimile (WWP)
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)
WI^3	Weather Impacts Information Integration (AF)
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
WMC	World Meteorological Center(s) (WWP)
WMO	World Meteorological Organization
WMSCR	Weather Message Switching Center-Replacement (FAA)
WOCE	World Ocean Circulation Experiment (NOAA/NESDIS)
WPDN	Wind Profile Demonstration Network (NOAA)
WPSM	Warfighter Physiological Status Monitoring (Army)
WRD	Water Resources Division (DOI/USGS)
WRF	Weather Research and Forecast (NOAA/OAR)
WRS	Weather Reconnaissance Squadron (AF)
	Weather Squadron (AF)
WSDDM	Weather Support to Deicing Decision Making (FAA)
WSP	Weather Systems Processor (FAA)
WSR-88D	Weather Surveillance Radar-1988 Doppler (NEXRAD)
WSSRAP	Weldon Springs Site Remedial 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)
YMP	Yucca Mountain Project (DOE)


FEDERAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (FCMSSR)
FEDERAL COORDINATOR FOR METEOROLOGY
INTERDEPARTMENTAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (ICMSSR)
PROGRAM COUNCILS
STANDING COMMITTEES
ENVIRONMENTAL SERVICES, OPERATIONS AND RESEARCH NEEDS
• Environmental Services and Requirements
▸ Hydrometeorology and Water Resource Management
▸ Waterways and Surface Transportation
▸ Natural Hazards
▸ Atmospheric Transport and Diffusion
▸ Marine Environmental Services
▸ Specialized Services (Air Quality, Agriculture and Fire)
• Natural Disaster Reduction / Post Storm Data Acquisition
• Hurricane and Winter Storms Operations and Research
• Satellite Telemetry
OPERATIONAL PROCESSING CENTERS
• Cooperative Support and Backup
▸ Observations
▸ High Performance Computing and Communications
ENVIRONMENTAL INFORMATION SYSTEMS AND COMMUNICATIONS
• Meteorological Codes
• Communications Interfaces and Data Exchange
▸ Data Requirements
▸ Communications Requirements
INTEGRATED OBSERVING SYSTEMS
• Atmospheric Observing Systems
• Marine Coastal Ocean Observing Systems
▸ Cooperative Network Modernization
▸ Hourly Precipitation Data
COOPERATIVE RESEARCH
CLIMATE MONITORING AND SERVICES
▸ Climate Reference Network
NATIONAL SPACE WEATHER
COMMITTEE FOR SPACE WEATHER
NATIONAL AVIATION WEATHER
▸ Aviation Weather
COMMITTEE FOR AVIATION SERVICES AND RESEARCH
• Volcanic Ash
LEGEND: • Designates a Working Group
▸ Designates a Joint Action Group