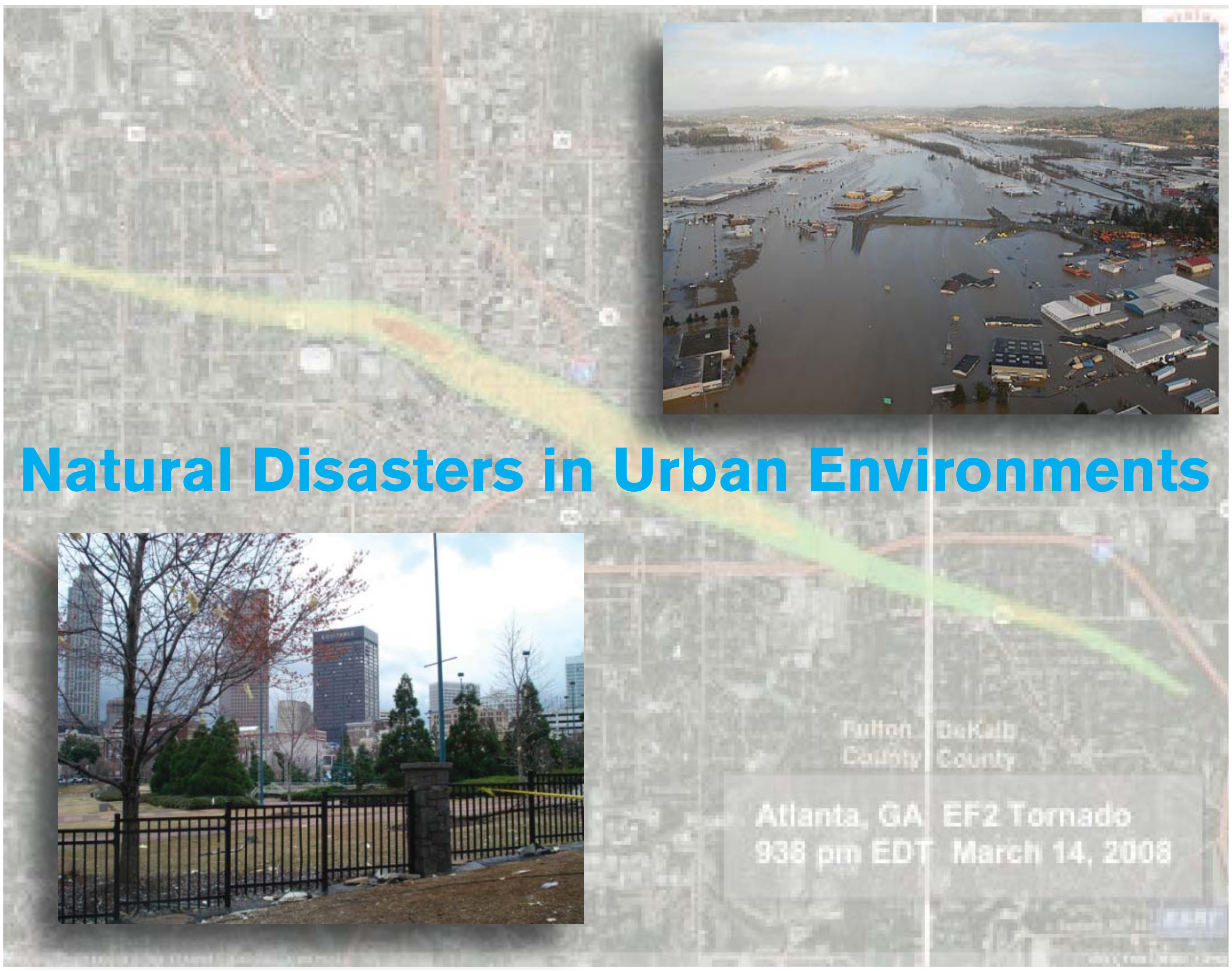
# The Federal Plan for Meteorological Services and Supporting Research Fiscal Year 2009




## Natural Disasters in Urban Environments

OFCM

OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY

FCM-P1-2008

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

Pictures displayed on the cover.

**Bottom Left:** Tornado damage from Atlanta storm. [NOAA-NWS photo]
**Middle:** Atlanta, GA tornado path and intensity. [NOAA-NWS photo]
**Top Right** Interstate 5 under the flood water in Seattle, Washington. [WSDOT photo]

# The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 2009


FEDERAL COORDINATOR
FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

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# PREFACE

Since 1965, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) has developed a Federal Plan that articulates the provision of meteorological services and the support for meteorological and related research by agencies of the Federal government. The 2008 Federal Plan provides Congress and the Executive Branch with a comprehensive compilation of proposed programs for fiscal year (FY) 2009 and a review of agency programs in FY 2008. The Federal Plan's narratives, timelines, and schedules are current as of November 2008.

The Federal Plan consists of an Executive Summary, three sections, and Appendices. The Executive Summary, which is written as a concise, stand-alone report, provides a high-level view of the Federal resources dedicated to meteorological programs and the achievements of those programs.

This year's feature article (Section 1) focuses on recent natural disasters that have impacted urban areas in the United States. These disasters are categorized into five areas: severe weather, homeland security, air quality, water quality, and climate. The purpose of this article is to raise the awareness of the increasing problem of urban natural disasters.

Section 2 of the Federal Plan summarizes the resources appropriated by Congress for FY 2008 and the resources requested in the President's FY 2009 Budget. Section 3 contains departmental and agency narratives on programs for providing meteorological services and supporting research and development. It also describes relevant research funded by the National Science Foundation.

Appendix A describes the OFCM's coordination, program, and planning activities. Appendix B addresses the World Meteorological Organization's World Weather Program. Appendix C lists the feature articles published in previous Federal Plans. The acronyms and abbreviations used throughout this year's Federal Plan are defined in Appendix D. The inside front cover lists the current members of the Federal and Interdepartmental Committees for Meteorological Services and Supporting Research, which provide guidance and support for OFCM activities. The inside back cover diagrams the infrastructure through which the OFCM performs its coordinating mission.

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

# THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH, FISCAL YEAR 2009

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# THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH FISCAL YEAR 2009 EXECUTIVE SUMMARY

For Fiscal Year (FY) 2009, the President's budget requests over a total of $4.49 billion for meteorological services and supporting research. Of the requested total, over $3.20 billion is designated for operations and over $1.29 billion for supporting research. Table ES-1 lists a breakout of the FY 2009 budget proposal.

For FY 2009, 98.1 percent of the total funds requested will go to the Department of Commerce (DOC), the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the Department of Transportation (DOT). The distribution among these four agencies is DOC 49.8 percent, DOD 21.9 percent, NASA 16.5 percent, and DOT 9.9 percent. The other Federal agencies will share the remaining 1.9 percent.

Table 2-1 shows the total FY 2009 request represents an increase of 7.4 percent above the over $4.18 billion appropriated in FY 2008. Within the four agencies mentioned above, DOC's request is an increase of 12.6 percent, DOD a decrease of 5.4 percent, NASA's request is an increase of 12.9 percent, and DOT has a 7.9 increase. The overall DOC increase is mainly the result of increases in NESDIS requested funding. DOD's decrease is attributable to a decrease in DMSP and Navy operations requests.

The budget requests for the other departments are as follows:

- Department of Agriculture (USDA): decrease of 9.7 percent,
- Department of the Interior (DOI): no change,
- Environmental Protection Agency (EPA): no change,
- Nuclear Regulatory Commission (NRC): large percent increase of over 300 percent stemming from an increase from $120K appropriated to $500K requested.

All agencies project a personnel total of 11,286 full-time equivalent (FTE) to be employed in Federal meteorological operations in FY 2009. This figure represents a decrease of less than one percent from the 11,383 FTE employed in FY 2008.

**Table ES-1. Federal Budget for Meteorological Operations and Supporting Research, FY 2009 (in thousands of dollars)**

| Agency | Operations | % of TOTAL | Supporting Research | % of TOTAL | TOTAL | % of TOTAL |
|---|---|---|---|---|---|---|
| Agriculture | 16,335 | 0.5 | 29,063 | 2.3 | 45,398 | 1.0 |
| Commerce | 2,113,708 | 66.1 | 122,798 | 9.5 | 2,236,506 | 49.8 |
| Defense | 625,045 | 19.6 | 357,612 | 27.7 | 982,657 | 21.9 |
| Homeland Security | 23,060 | 0.7 | 0 | 0.0 | 23,060 | 0.5 |
| Interior | 2,400 | 0.1 | 0 | 0.0 | 2,400 | 0.1 |
| Transportation | 408,033 | 12.8 | 38,252 | 3.0 | 446,285 | 9.9 |
| EPA | 0 | 0.0 | 9,000 | 0.7 | 9,000 | 0.2 |
| NASA | 7,497 | 0.2 | 733,212 | 56.8 | 740,709 | 16.5 |
| NRC | 500 | 0.0 | 0 | 0.0 | 500 | 0.0 |
| TOTAL | $3,196,578 | 100 | $1,289,937 | 100 | $4,486,515 | 100 |

## MAJOR PROGRAMS--DOC, DOD, NASA, AND DOT

### NEXT GENERATION WEATHER RADAR (NEXRAD)

NEXRAD is the joint National Weather Service (NWS), Federal Aviation Administration (FAA), and Department of Defense (DOD) weather radar system consisting of 159 operational radars. NEXRAD utilizes Doppler technology and hydrometeorological processing to provide significant improvements over the previous generation of weather radars for tornado and thunderstorm warnings, air safety, flash flood warnings, and water resources management. The system is modular in design, upgradeable, has long life cycle expectancy, and provides its principal users with a wide array of automated weather information that will increase their capability to meet their respective operational requirements.

The NEXRAD Program, which was initiated 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 four years later in February 1994. The original program plan called for a total of 161 radars. In response to a National Research Council report, 3 additional radars were deployed, which raised the total to 164 radar sites (158 operational sites and 6 support sites). By agency, as of June 2001, the Department of Commerce (DOC)/NWS had commissioned 120 operational sites, the DOD (USAF and Army) had commissioned 26 sites (within the United States and overseas), and the Department of Transportation (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, the NWS Training Center in Kansas City, Missouri, and the Radar Operations Center, Oklahoma City, Oklahoma. In 2004, an additional WSR-88D was commissioned in Evansville, Indiana, to augment coverage for southern Indiana and western Kentucky, bringing the count of operational radars to 159.

The NEXRAD Program has an ongoing process of modifying, retrofitting, and enhancing NEXRAD hardware and software. These efforts target obsolescence avoidance, improved operational reliability, lower operating costs, higher quality data, and meeting new operational requirements. The next major NEXRAD enhancement is to add a dual polarization capability which will improve radar precipitation accumulation estimates, hail and icing conditions, and higher data quality. The dual polarization capability is expected to begin deployment in 2010.

### AUTOMATED SURFACE OBSERVING SYSTEM (ASOS)

ASOS is the primary minute-by-minute, 24-hour weather observation system for NWS, FAA, and DOD. ASOS generates the basic Aviation Routing Weather Report (METAR) and Aviation Selected Special Weather Report (SPECI). This information is essential for safe and efficient aviation operations and is used by the public to plan day-to-day activities. ASOS also provides valuable information for the hydrometeorologic, climatologic, and meteorologic research communities.

The ASOS program began in 1983 as a joint development effort between the DOC/NWS, DOD, and DOT/FAA. Installation of ASOS units started in 1992. Implementation of ASOS into NWS field operations provides continuous weather watch and yields improved staff productivity. A total of 1,003 units have been purchased. The NWS has purchased, accepted, and commissioned 312 sites. The FAA has purchased 573 units, all of which have been accepted and commissioned by the NWS. The Navy has purchased and accepted 71 sites. The Air Force has purchased and accepted 47 sites.

The ASOS Product Improvement Program was established in 1999 to address technology insertion and system improvement. Agency priorities have been established for seven improvement areas. Replacement of the under-powered ASOS processing unit and re-hosting of the ASOS software was the highest priority effort, and was successfully completed in 2005. Replacement of the temperature dewpoint sensor, necessitated due to excessive required maintenance, was completed in 2005 as well. In 2005, NWS systems were upgraded with the All Weather Precipitation Accumulation

Gauge (AWPAG) to meet NWS climatology needs. The mechanical cup and vane wind sensors, subject to freezing, were replaced by the Ultrasonic Wind Sensor in 2007. A replacement for the logistically unsupportable legacy cloud height sensor will be fielded beginning in 2010, and will be followed by a new sensor to provide automatic reporting of drizzle, hail, and ice pellets. The last of the prioritized efforts, incorporation of a sunshine duration reporting capability, is expected to begin in 2011.

AUTOMATED WEATHER INFORMATION SYSTEMS (AWIS)

The DOC, DOD, and DOT require AWIS to facilitate the collection, processing, and interpretation of meteorological data. AWIS are procured to provide an automated, high-speed, user-friendly interface to access and process large volumes of sophisticated meteorological data. AWIS programs support the timely production of accurate and geographically precise warnings, forecasts, and special tailored products. They also provide the communications capability for expeditious product dissemination.

Major agency systems classified as AWIS are: NOAA's Advanced Weather Interactive Processing System (AWIPS), FAA's Weather and Radar Processor (WARP); Air Force's Joint Environmental Toolkit (JET); and the Naval Integrated Tactical Environmental Subsystem (NITES).

AWIPS

In February 1997, the Secretary of Commerce approved the limited deployment of AWIPS at over 40 sites. 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 load (Release 4.2) was successfully conducted from mid-May through June 1999. AWIPS commissioning began in January 2000 and was completed in November 2000 with 141 NWS systems commissioned at 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), the Spaceflight Meteorology Group (SMG), and the National Centers for Environmental Prediction (NCEP).

The NWS successfully completed the final development release of AWIPS (Build 5) in early 2003, completed deployment of its first Operational Build (OB1) that summer, OB2 in December 2003, OB3 in August 2004, OB4 in February 2005, and OB5 in December 2005. Additional AWIPS releases were deployed to field offices as OB6 in February 2006, OB7.1 in October 2006, OB7.2 in January 2007, OB8.1 in July 2007, and OB8.2 in January 2008. OB8.3 began deployment in mid-June 2008. The AWIPS Operational Builds deliver new functionality, enhancements, and fixes for the areas of warning product generation and support, hydrological product generation, forecast generation, data and imagery display, communications, and infrastructure.

Significant activities underway include the re-architecture of the current AWIPS software, which is known as AWIPS-II, and is planned for deployment starting in 2010. AWIPS-II will transition the system to a Service Oriented Architecture (SOA), and will require extensive testing to validate whether it can meet or exceed the performance of the software currently deployed in the field. A follow-on project, AWIPS-II Extended, will enable AWIPS to be the visualization system for the entire NOAA Weather Enterprise. AWIPS-II will include a Thin Client capability, which is essential for AWIPS-like operations for NWS Weather Service Offices (WSOs), Incident Meteorologists (IMET) in the field, and NCEP.

WARP

The FAA's 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.

JET

JET will replace several disparate legacy weather systems with a single, integrated means of supporting both garrison and deployed operations, including a "first-in" weather forecasting capability. Combining forecasting, product-tailoring, and mission-impact capabilities in an interactive, network-centric, standards-based package; JET accesses, processes, analyzes, tailors, and integrates terrestrial and space weather information into command and control systems to guide warfighter decision making. This effort will eliminate Air Force weather weapon system redundancies and inefficiencies, reduce the burden on system administrators, and ultimately extend, consolidate, or replace the following systems: Operational Weather Squadron Production System Phase II, the New-Tactical Forecast System, the Joint Weather Impacts System, and the Army's Integrated Meteorological System Weather Toolkit.

NITES

A series of NITES variants (I - IV) were re-engineered from the Tactical Environmental Surveillance System and other legacy systems of the early 1990's. NITES has capabilities to ingest, process, fuse, display, and disseminate meteorological and oceanographic (METOC) information and its impact on tactical operations. In early 2000, the NITES II application software was redesigned to align with the Global Command and Control System (GCCS) Family of Systems 4.x, provide increased flexibility, enable operating system and/or hardware independence, and improve user operability with a new graphical-user interface for tactical decision aid applications. The NITES II redesign suite of software is integrated with both GCCS-Maritime (M) and GCCS-Joint (J) 4.x versions.

The Navy will field a follow-on system, called "NITES – Next," to increase the capabilities for ashore, afloat and mobile METOC support to naval tactical operations and be net-centric and interoperable with the other services. NITES – Next will be a software only solution and compliant with the DOD Global Information Grid and Navy FORCEnet architectures. Navy is coordinating with the Air Force to efficiently and effectively leverage the Air Force's Joint Environmental Toolkit (JET) Program to eliminate unnecessary duplication of METOC capabilities.

THROUGH-THE-SENSOR (TTS) CAPABILITIES

The Hazardous Weather Detection and Display Capability (HWDDC) and Tactical Environmental Processor (TEP) are TTS technologies which will passively tap the AN/SPS-48G(V) (HWDDC) and SPY-1 (TEP) 3D air search radars to obtain and display hazardous weather information. The TEP and HWDDC systems will be based off common modular weather processing algorithms, and will have similar data product and display capabilities. Essentially, they are one common set of processing applied to two different radars. The differences in capabilities supported by the systems are driven by the differences in the radars, themselves.

The HWDDC will be integrated into the baseline AN/SPS-48G air-search radar, allowing it to extract and display reflectivity data. HWDDC addresses a long-standing fleet requirement for real-time hazardous weather detection/display to support safety of flight and operations planning within Carrier and Expeditionary Strike Groups. The knowledge of hazardous weather conditions afloat greatly enhances readiness and combat posture.

The TEP, which will be installed on modernized Destroyers (DDG), provides not only convective weather detection and display, but also real-time volumetric wind profiles and radar refractivity assessments for SPY-1 radar returns. This Refractivity from Clutter (RFC) capability supports SPY-1 optimization, which is critical in rapidly changing afloat refractivity environments. RFC enhances detection capability of small surface vessels and low-flying aircraft, while also significantly contributing to improvement in atmospheric modeling quality.

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES (GOES)

The GOES spacecraft circle the Earth in a geosynchronous orbit. This means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. These satellites provide continuous monitoring necessary for effective, detailed, and extensive near-term severe weather monitoring and fore-casting and long-term environmental monitoring. GOES-East at 75°W and GOES-West at 135°W provide data on the United States and the Western Hemisphere. GOES-East monitors North and South America and most of the Atlantic Ocean. GOES-West monitors North America and the Pacific Ocean basin. In FY 2009, the next spacecraft in the current GOES series will be launched. GOES-O is slated to launch in December 2008 and will become an on-orbit spare (GOES-14).

## NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

The NPOESS Program began when Presidential Decision Directive (PDD) NSTC-2 established the Integrated Program Office (IPO) in October 1994. Under the terms of this PDD, the IPO's function is to "...reduce the cost of acquiring and operating polar-orbiting environmental satellite systems, while continuing to satisfy Department of Defense (DOD) and Department of Commerce (DOC) operational requirements for data from these systems." Effectively, the directive combines the current operations and future follow-on activities of the DOD Defense Meteorological Satellite Program with the DOC NOAA Polar-orbiting Operational Environmental Satellite program. The new follow-on system will be called NPOESS. Cooperation with foreign governments and international organizations are to be encouraged as well.

NPOESS is an integrated DOC, DOD, and National Aeronautics and Space Administration (NASA) program. Through the IPO, DOC is responsible for operations and overall program management; DOD is responsible for the acquisition and launch of the satellites; and NASA is responsible for insertion of new and innovative technology.

In January 2006, the program was expected to exceed its approved program baseline by 25 percent. This required the DOD to recertify the program to Congress in accordance with the Nunn-McCurdy Amendment of the 1982 Defense Authorization Act. The program configuration was reduced from three to two orbital planes and from six to four satellites.

The space segment of NPOESS will include space platforms and sensors that will collect and store environmental and other data until it can be downlinked directly to operational weather processing centers (e.g., Air Force Weather Agency, Fleet Numerical Meteorology and Oceanography Center, Naval Oceanographic Office, and National Environmental Satellite, Data, and Information Service (NESDIS)) and field terminals (receivers used by deployed and/or remote military units and civilian users to obtain environmental data). The space segment will consist of meteorological, oceanographic, terrestrial, space environmental monitoring, climatic sensors, and other capabilities such as surface data collection and/or location and aid to search and rescue operations. The satellite will store and download all data to ground stations with a latency of less than 90 minutes and will also provide continuous downlink of data for receipt by worldwide civilian and DOD users.

The NPOESS constellation will notionally consist of U.S. satellites in two orbital planes and will receive data from one European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) satellite via European ground sites. The US satellites will fly at 833 ± 17 km altitude with an inclination of 98.7 ± 0.05 degrees in two distinct sun-synchronous orbits: early morning and early afternoon. EUMETSAT will cover the mid-morning orbital plane.

Each satellite will carry several types of sensors to accomplish its mission, including electro-optical (E/O), microwave (MW), and space environment (the exception is the first NPOESS satellite, C1, which will not carry a space environment package). The E/O instruments include a Visible/Infrared Imager/Radiometer Suite to provide imagery in the visible and infrared spectra, a cross-track infrared sounder to provide high-resolution vertical profiles of atmospheric properties in conjunction with MW soundings, and an ozone mapping and profiler suite to measure ozone in the earth's atmosphere.

NPOESS will carry other payloads that are similar to existing instruments, such as NOAA's managed data collection system (DCS), which collects, processes, and stores for subsequent transmission buoy, free-floating balloon, and remote weather station measurements; and the search and rescue satellite aided tracking (SARSAT) system that uses NOAA satellites in low-Earth and geostationary orbits to detect and locate users in distress. The satellites relay distress signals from emergency beacons to a network of ground stations and ultimately to the SARSAT U.S. Mission Control Center (USMCC) in Suitland, Maryland. USMCC alerts the appropriate search and rescue authorities.

NPOESS also recently sponsored the University Corporation for Atmospheric Research Cooperative program for Operational Meteorology, Education, and Training (COMET) in branching into high-latitude territory. Since the usefulness of geostationary satellites declines rapidly at latitudes above 60° north and south, NPOESS data are especially important toward the poles. COMET is developing a series of modules to help prepare forecasters for the products available from the polar orbiters.

The IPO is working with the NPOESS contractor to ensure ground systems are in place and operating in time to use NPOESS Preparatory Project data in 2010 and that all systems are ready for an expected 2013 launch of the first operational NPOESS satellite.

NASA's FY 2009 request is for just over a total of $740.7 million--over $7.50 million for operations and $733.2 million for supporting research. 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.

OTHER AGENCY PROGRAMS

For FY 2009, the Department of Agriculture (USDA) requested $45.4 million for meteorological operations and supporting research. Operationally, the USDA supports specialized weather observation networks and also conducts an active supporting research program to ensure an abundance of high-quality agricultural commodities, while minimizing the adverse effects of agriculture on the environment. 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 2009 request of $2.4 million is primarily to support the Bureau of Land Management's Remote Automatic Weather Station (RAWS) program.

The Environmental Protection Agency (EPA) budget request for FY 2009 is $9.0 million, the same amount as in FY 2008, to provide user-appropriate and scientifically credible air-quality and meteorological programs and models to support regulatory applications.

The Nuclear Regulatory Commission's (NRC's) request for $500,000 in FY 2009 is for operations. With an increased emphasis on nuclear energy, the NRC will dedicate the increased funding to obtain and analyze meteorological data and information related to siting more new nuclear power plants than last year and continued safe operation of nuclear facilities, to the protection of public health and safety, and protection of the environment.

## FEDERAL COORDINATION

NATURAL DISASTER REDUCTION

INTERDEPARTMENTAL HURRICANE CONFERENCE

The OFCM annually hosts the Interdepartmental Hurricane Conference (IHC) 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. The 62nd IHC in Charleston, South Carolina, March 3-7, 2008, was attended by approximately 200 people including representatives from nine Federal agencies. Objectives of the 2008 IHC included the following: (1) review the Nation's tropical cyclone forecast and warning program from end-to-end; (2) update the National Hurricane Operations Plan for 2008; (3) review the 2007 Joint Hurricane Testbed (JHT) projects, and identify candidates that may be successfully transitioned into operations; (4) examine how hazard risk reduction improvements can be made through stronger local partnerships and alliances; and (5) as recommended in the Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead, begin developing an interagency implementation strategy for the tropical cyclone research priorities. Actions resulting from the conference included: (1) Update and execute the National Hurricane Operations Plan for the 2008 hurricane season; (2) Analyze tropical cyclone research activities presented at the 62nd IHC and other subsequent forums with respect to the priorities established in Table 5.1 of the interagency strategic research plan; (3) Identify overlaps, gaps, areas for collaboration and leveraging opportunities; and (4) Establish the next steps needed to fill the gaps. The IHC was extremely successful in bringing the operational and research communities together to further improve the tropical cyclone forecast and warning program. Finally, the conference provided a baseline of research activities that will enable the development of an interagency implementation strategy for the tropical cyclone research priorities, which can be reviewed at subsequent IHCs. The 63rd IHC is being planned for March 2009 in St. Petersburg, Florida.

TROPICAL CYCLONE RESEARCH AND DEVELOPMENT PLAN

The tropical cyclone forecast and warning program is an interdepartmental collaboration to provide the United States and designated international recipients with forecasts, warnings, and assessments concerning tropical and subtropical weather systems. The Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead provides a strategy to improve the effectiveness of operational forecasts and warnings through increased collaboration among the major players in the operational and research and development (R&D) communities. This strategic plan has become the underpinning of NOAA's Hurricane Forecast Improvement Program and provides a foundation for Navy and NASA research as well as supporting NSF's related activities. In response to direction from the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR), the OFCM formed the Working Group for Tropical Cyclone Research with cochairs from NOAA and the Navy in the summer of 2008. In FY 2009, the Working Group will be developing an implementation strategy for the research objectives outlined in the strategic plan.

POST-STORM DATA ACQUISITION

The OFCM continued to coordinate, as required, timely post-storm data acquisition surveys in response to Presidentially declared natural disasters and other agency requirements. Under the 5-year Umbrella Agreement and an FY 2008 funding agreement between OFCM and the U.S. Air Force for up to $22,000 in reimbursable support, the Civil Air Patrol flew 17 missions in support of tornado and hurricane damage assessments, flood assessment, survey of potential dam breaks, glacial lake damming in Alaska, and a pre-storm hydrology survey in Hawaii. This support will continue in FY 2009 at a planned level of $25,000 set aside for these missions.

URBAN METEOROLOGY

NATIONAL WILDLAND FIRE WEATHER NEEDS ASSESSMENT

The needs assessment has been completed, capabilities information has been gathered, and an initial gap analysis has been accomplished. The needs assessment identified 47 specific needs in nine functional areas and the preliminary gap analysis indicates just two of these needs may have no activity against them but, conversely, none of the needs may be considered fully met at this time. The OFCM briefed the results of the needs assessment and provided a copy of the summary report to the NOAA Science Advisory Board's Working Group on Fire Weather Research as part of their kickoff activities in October 2007. The results of the NOAA SAB's working group study have been incorporated into the draft final report. In FY 2009, the Working Group for Wildland Fire Weather will complete the final report which will outline the needs, capabilities, gaps, and a framework to address the needs.

ATMOSPHERIC TRANSPORT AND DIFFUSION RESEARCH AND DEVELOPMENT

The Joint Action Group for Joint Urban Test Beds (JAG/JUTB), under the Working Group for Urban Meteorology (WG/UM), is continuing work to develop an operational concept document for multifunctional joint urban test beds to provide services and data to model developers, test and evaluation personnel, and users. The joint urban test beds will support the following functional areas: severe weather (e.g., hurricanes, tornadoes, heat waves and cold spells, drought, and wildland fires), homeland security (dispersion of hazardous materials), climate, air quality (e.g., particulate matter aerosols), and water quality (e.g., deposition of airborne contaminants on water sources and waterborne transport of contaminants). JAG/JUTB is currently planning to pursue implementation of a JUTB over the National Capital Region first; this JUTB would be the proof of concept and our experience with it would allow for the improved development of an operational concept document based upon experiences with this first JUTB.

GEORGE MASON UNIVERSITY ATMOSPHERIC TRANSPORT AND DISPERSION MODELING CONFERENCE

George Mason University (GMU), Fairfax, Virginia, conducted its 12th Annual Conference on Atmospheric Transport and Dispersion Modeling in July, 2008, and the OFCM cosponsored the event together with a number of other agencies. Technical topics of interest for the conference were: new developments in basic theories of boundary layer models and transport and diffusion models; urban-scale meteorological and dispersion experiments and models; computational fluid dynamics (CFD) model theory and applications; field experiments and laboratory experiments concerned with boundary layer studies and turbulence and dispersion studies; mesoscale meteorological modeling for input to transport and dispersion models; the use of remote sensing technology in boundary layer and transport and dispersion studies; model evaluation methods, uncertainty/sensitivity analyses, and risk assessments; improvements in model inputs (e.g., land-use data, 3-D building data) and output visualizations; and methods and criteria for emergency response and decision making.

OPERATIONAL PROCESSING

Interagency cooperation continued to improve processing and backup capabilities of NOAA's National Centers for Environmental Prediction and Office of Satellite Data Processing and Distribution, the Air Force Weather Agency, and the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center and Naval Oceanographic Office. In FY 2008, the agencies signed the Data Acquisition, Processing, and Exchange (DAPE) Memorandum of Agreement to update and formalize these activities among the operational processing centers, and the Environmental Satellite Data Acquisition (ESDA) annex to the DAPE MOA is in final coordination to be completed in FY 2009. This annex will replace the expiring Shared Processing Program (SPP) agreement which provides for funding to support the exchange of extensive volumes of data.

WEATHER INFORMATION FOR SURFACE TRANSPORTATION

In 2008, the interagency weather community continued to move forward in support of surface transportation. The Fourth National Symposium on Surface Transportation Weather was held in Indianapolis, Indiana, in June 2008 and several U.S. representatives attended the Safety in Mobility conference held in Velden, Austria, in July 2008. At the invitation of the U.S. Embassy in Austria, the Federal Coordinator for Meteorology provided a keynote address. Agency representatives attended the Intelligent Transportation System World Congress in New York City in November 2008. In FY 2009, the interagency community will focus on areas such as: current and emerging capabilities; transition of research to operations to improve products and services; getting the right message out and the need for social science involvement; education and outreach; the need for metrics to measure success and guide resource allocation; identifying gaps and setting research priorities; and exploiting the opportunity for a near-term intermodal initiative to develop and demonstrate emerging capabilities.

AVIATION WEATHER

Agency representatives continued to participate in the Next Generation Air Transportation System (NextGen) Weather Working Group and the Friends/Partners in Aviation Weather (FPAW). The OFCM presented results of the 10-year National Aviation Weather Program effort to reduce weather-related aviation accidents at a National Aviation Weather Program Council meeting and at the FPAW meeting at the National Business Aviation Association annual conference. The goal was to reduce weather-related fatal aviation accidents by 80 percent over the 10-year period from 1997 through 2006. Although the National Aviation Weather Program achieved significant progress over this period, particularly in the area of general aviation, the second five years of the 10-year period showed a marked slow down in the decline of accident rates and the ambitious 80 percent reduction goal was not achieved. The OFCM will be working with the NTSB and others in

FY 2009 to develop an understanding of the change in the trend lines, how the program can sustain the progress which has already been made, and how to jump start additional progress toward the overall 80 percent reduction. The final report assessing this goal will be published in FY 2009.

## SPACE WEATHER

The Committee for Space Weather is refining the draft and expects to publish the new NSWP Strategic Plan in FY 2009, with a follow-on effort to craft an updated Implementation Plan. In a complementary effort, the Committee prepared and submitted a Space Weather Implementation Plan (SWxIP) as requested by the Committee on Environment and Natural Resources (CENR) Subcommittee for Disaster Reduction (SDR). The SWxIP is in final review within the Executive Office of the President and publication is expected in 2009. Another significant NSWP effort in FY 2008 was the completion of the report Impacts of NPOESS Nunn-McCurdy Certification and Potential Loss of ACE Spacecraft Solar Wind Data on National Space Environmental Monitoring Capabilities, documenting the results of a study requested by the Office of Science and Technology Policy (OSTP). The For Official Use Only report identifies a number of significant impacts resulting from the expected loss of significant space environmental sensing capabilities. The space weather community received a follow-on request from OSTP to conduct a mitigation study in FY 2009.

## PHASED ARRAY RADAR

The interagency weather community continued to move forward with a coordinated approach to risk reduction for applying multifunction phased array radar (MPAR) to weather detection and concurrent air and weather surveillance. The MPAR Symposium in October 2007 highlighted that now is the time to begin the evaluation of MPAR, and a risk-reduction implementation strategy was needed. The WG/MPAR developed a coordinated implementation strategy in early 2008, which formed the anchor point for ongoing planning and coordinated action across NOAA, DOD, DHS, and the FAA. The Working Group for MPAR (WG/MPAR) completed a service improvement assessment for weather surveillance which mapped the linkages from basic capabilities expected of a PAR system, to derived capabilities, and subsequently to anticipated service improvements. Also in late FY 2008, the National Academies' Board on Atmospheric Science and Climate (BASC) Committee on the Evaluation of the MPAR Planning Process delivered their report. Their overarching recommendation was to continue the MPAR research and development. The WG/MPAR is defining requirements and drafting an operations concept for MPAR. Over the last year, DHS supported targeted research using the National Weather Radar Testbed at the National Severe Storms Laboratory in Norman, OK, and additional future funds were programmed for phased array radar work in NOAA. At its meeting on September 29, 2008, the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) supported the creation of a senior policy council for MPAR within the Federal meteorological coordinating infrastructure. This council would begin addressing policy issues among the key stakeholding agencies as anticipated funding increases materialize in the years ahead.

## CROSSCUTTING HYDROMETEOROLOGICAL ASSESSMENT

In September 2008, a one-day interagency hydrometeorology mini-workshop by OFCM brought together the relevant Federal agencies to initiate discussion on topics such as programs, product suites and services, needs and requirements, transitioning research into operational applications, and related education and outreach activities. The workshop spurred interest among the participants to see what others are working on and to continue gathering needs and requirements and identifying priorities and gaps. A follow-on mini-workshop is planned for December 2008.

## CRITICAL SKILL SHORTAGES

The interagency weather community has already identified a deficiency in advanced data assimilation expertise and anecdotal evidence indicates additional potential shortages in the areas of probability, radar meteorology, and tropical meteorology. Senior leaders agreed to establish the Joint Action Group for Critical Skill Shortages to identify other critical areas, collect information, and conduct an analysis of the Federal sector's current and projected critical skill shortages. The group will then make recommendations to address the skill shortages identified.

# SECTION 1

# NATURAL DISASTERS AND HIGH IMPACT EVENTS AFFECTING URBAN COMMUNITIES

## Introduction

In late summer 2008, a large portion of the United States population was preparing for or enduring the effects of the Atlantic hurricane season as the U.S. coastline experienced tropical cyclones such as Hurricane Gustav, Tropical Storm Hanna, and Hurricane Ike. As these systems approached the coastline and multiple major urban areas, they tested several of the lessons learned from Hurricane Katrina just three years before. Would people evacuate the coastal communities? What would be the impact on gas prices? Where would the storm make landfall? How strong would the storm be at landfall? Would the local, State, and Federal government agencies be prepared? These were just some of the questions on the minds of U.S. citizens and government officials. As the hurricane season continued, the threat of tropical cyclones highlighted the significance of natural disasters and other high impact events on urban communities.

Of the approximately 281 million people living in the U.S. in 2000, more than 68 percent lived in urban areas comprising just two percent of the U.S. landmass [1]. The built environment in these urban areas significantly alters the meteorology of the area, including temperatures, humidity, winds, and precipitation. It also alters air and water quality, what happens to precipitation reaching the ground, and the climate itself. Although the effects of the built environment vary by areal coverage, vertical extent, and types and distribution of structures and pavements, "urban" in this context includes small towns and not just major metropolitan areas. The unique aspects of this environment present special challenges for the meteorological community to meet the increasing demands of the urban population for improved products and services.

In 2004, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) published a report entitled *Urban Meteorology: Meeting Weather Needs in the Urban Community* [2] which highlighted five primary elements within urban meteorology: severe weather, homeland security, air quality, water quality, and climate. This report and the subsequent September 2004 Forum on Urban Meteorology established a discussion framework to begin identifying needs, priorities, and common problems. The OFCM also initiated coordinated action moving forward in partnership to improve services in the urban environment. Today, the federal meteorological community is pursuing action on a number of fronts to bring these improved services to fruition. This article reviews some specific examples of high impact events in the urban environment, the associated challenges, and coordinated activity underway to improve products and services.

## Severe Weather

Severe weather as used in this context is not limited to tornadoes or localized convective storms with winds greater than 50 knots and large hail. Severe weather includes the range of high impact weather events including tornadoes, certainly, but also flooding rains, tropical cyclones, ice storms, snow storms, and extreme heat and cold, for example. Please note that beginning in 2007, the strength of tornadoes is classified using the new Enhanced Fujita (EF) scale (see Table 1), which is referred to in subsequent sections. The following sections describe several severe weather events and specific impacts on urban areas.

<u>Tornadoes</u>

*Greensburg, Kansas Tornado – May 4, 2007.* The most devastating tornado of 2007 occurred on May 4 when just after 9:30 p.m., the town of Greensburg, Kansas, suffered a direct hit from an EF5 tornado. The huge tornado, over one and one-half miles wide, moved across the center of Greensburg and

Article prepared by Ronla Henry

**Figure 1:** Greensburg, Kansas, after the May 4, 2007, EF5 tornado. (Photo credit: NOAA)

the mayor later estimated 95 percent of the town of about 1,500 people had been completely destroyed (Figure 1). Ten people were confirmed dead in Greensburg as a result of this first tornado rated as an EF5. The last tornado rated in the highest category of the previous Fujita F-scale had occurred seven years earlier in Oklahoma. Two other tornado-related deaths happened in outlying areas that same evening as more than 20 tornadoes were reported. Although little can be done to reduce property damage in the face of an EF5 tornado, increasing warning accuracy and lead times can help save lives and reduce injuries.

| EF Number | 3 Second Gust (mph) |
|---|---|
| 0 | 65-85 |
| 1 | 86-110 |
| 2 | 111-135 |
| 3 | 136-165 |
| 4 | 166-200 |
| 5 | Over 200 |

**Table 1:** The Enhanced Fujita (EF) Scale for estimating tornadic wind speeds based on resulting damage, adapted from the National Weather Service Storm Prediction Center [3].

*Memphis and Nashville, Tennessee – February 5-6, 2008.* Eighty-two tornadoes struck the mid-South and Tennessee Valley in roughly a 12-hour period from the afternoon of Tuesday, February 5, through the early morning of February 6, 2008. Subsequent damage surveys indicated that, of the 82 tornadoes reported, five were violent EF4 tornadoes, five were rated EF3, and 15 were rated EF2, leaving 56 people dead in four states and making this event the deadliest tornado outbreak since May 31, 1985. All fatalities occurred with tornadoes categorized EF2 or greater.

One of those tornadoes, an EF2, affected southern parts of the Memphis, Tennessee, metropolitan area on February 5, 2008. As the storm moved through the southern Memphis suburbs, it affected Memphis International Airport, the Federal Aviation Administration air traffic control tower, and the NWS Weather Forecast Office (WFO), with personnel in the latter two locations evacuating their buildings during the storm. The tornado caused four fatalities in the Memphis area but the outcome could have been much worse. The tornado struck at the time of day when large numbers of school buses would normally have been on the roads, but Memphis city school officials had dismissed schools early on February 5 because of the storm warnings.

An EF2 tornado also hit Union University in nearby Jackson, Tennessee, on February 5, but there were no fatalities and only minimal injuries at the university. University officials attributed this to advance warning and a good emergency preparedness plan.

Later in the evening of February 5, an EF2 tornado affected portions of the Nashville metropolitan area and at the Sommet Center, officials temporarily halted a National Hockey League game and the fans sheltered in the arena during the storm. There were no fatalities in the Nashville area during this event but the same thunderstorm later produced an EF3 tornado northeast of Nashville, near the rural community of Lafayette, Tennessee, killing 22 people.

*Atlanta, Georgia – March 14, 2008.* Although conditions were less than optimum for tornadoes or severe thunderstorms, an isolated supercell developed just northwest of the city of Atlanta on the evening of March 14, 2008. This storm intensified as it moved into the city and it produced a tornado that caused damage along a six-mile path, stretching from west of the Georgia World Congress Center to western DeKalb County south of Interstate 20. The storm struck at 9:38 p.m. during a 2008 Southeastern Conference Men's Basketball Tournament game in the Georgia Dome in downtown Atlanta. The tornado passed just north of the dome and had the game not gone into overtime, thousands of fans

**Figure 2:** Downtown Atlanta, Georgia, after the March 14, 2008, tornado. (Photo credit: NOAA)

would have been in the streets headed to their vehicles or public transportation when the tornado hit, likely significantly increasing the number of deaths and injuries. This tornado was rated EF2, with maximum winds estimated to be 130 MPH. Figure 2 shows some of the damage in downtown Atlanta from this tornado. [4]

These tornado examples highlight the value of an effective warning system, well-designed and executed emergency plans, and the leadership of organizations who understand the severe weather threat and act on it. In addition to improving warning capability through potential new systems such as Multifunctional Phased Array Radar (MPAR) and better high-resolution weather forecasting models, the meteorological community needs to better understand the social sciences aspects of preparedness, warning, and response. These examples highlight the need for continued education and outreach to the public and public officials to improve response to warnings, and the interagency community is moving today to improve these capabilities.

<u>Seattle Area Flooding – December 1-3, 2007</u>

Three successive storms affected the Pacific Northwest on December 1-3, 2007. Fueled by remnants of Pacific Tropical Storms Hagibis and Mitag, the third storm to hit the Seattle area was the strongest. Heavy rainfall and rapidly melting snow produced record flooding in western Oregon and Washington State. The worst flooding occurred about 85 miles south of Seattle near Chehalis, Washington, where 10 feet of water covered a portion of Interstate 5 (Figure 3). Authorities closed a 20-mile stretch of the highway for several days, blocking the major thoroughfare between Seattle, Washington, and Portland, Oregon. According to the Washington State Department of Transportation (WSDOT), the closure cost the state's economy more than $47 million in economic output from the freight system alone. [5]

The Seattle-Tacoma official observing station received 5.57 inches of rain during this three-day period, with 3.77 inches (a record for the day) falling on December 3. NWS WFO Seattle received 4.15 inches of rain that day, setting an all-time record for 24-hour rainfall at that station. Major urban and small stream flooding occurred surprisingly rapidly in King County and the Seattle metropolitan area, an unusual occurrence for these areas. Despite significant road damage in King County, no fatalities were attributed to the flooding.

This case highlights the significant economic impacts of weather events in the urban environment even without widespread, violent destruction of infrastructure. It points to the importance of accurate, relevant, and timely hydrometeorological data and predictions and highlights the importance of weather information for surface transportation. The OFCM hosted mini-workshops on hydrometeorology needs in the fall of 2008 and continues to advance weather support for surface transportation. As in the tornado cases, advanced weather radars and integration of social sciences into the warning process can improve support to the public and protection of life and property.

<u>North American Ice Storm – January, 2007</u>

A series of winter storms plagued much of

North America in January, 2007. The first storm traveled from the Rio Grande Valley on January 11 to New England by January 16, followed immediately by another storm January 16–18 which affected the southern United States from Texas to the Carolinas. The final storm hit the southern plains and Mid-Atlantic States January 19–24.

**Figure 3:** Flooding of Interstate 5 near Chehalis, Washington, December 2007. (Photo credit: Washington State DOT, by Jim Walker)

These winter storms created a wide swath of damage, affecting several urban areas including St. Louis, Missouri; Dallas-Forth Worth, Texas; San Antonio, Texas; Columbia, South Carolina, and both Raleigh and Charlotte, North Carolina. Heavy snow and ice accumulations on power lines, towers, and trees caused extensive damage across the area, resulting in multiple power outages for hundreds of thousands of residents in these states with some outages lasting up to a week.

The winter weather also significantly disrupted multiple modes of transportation when snow-covered or icy roads caused numerous traffic accidents, rail traffic slowed to a crawl, and ground delays scrambled airline schedules. In Oklahoma, a truck carrying hazardous material slid off of a river bridge. No one was injured, but the truck's hazardous cargo disappeared into the water.

These storms resulted in at least 87 lives lost as well as significant clean-up and repair costs, highlighting the need for improved hydrometeorological predictions, weather information for surface transportation, and effective ways to convey anticipated impacts to the public and public officials.

Improving Products and Services for Severe Weather

The OFCM and the federal meteorological community are working together in a number of ways to improve products and services to better serve the nation's urban population leading up to and during the types of high-impact weather events described above. The Multifunction Phased Array Radar (MPAR) risk reduction effort seeks to explore the potential of phased array radar to more rapidly detect the precursors and onset of tornadic conditions and for improved weather surveillance overall, including heavy precipitation and discriminating rain/ice/snow events. The community is also working together in the area of weather information for surface transportation, moving ahead to bring more and improved information to vehicle operators of all types; highway, railway, waterway, pipeline, and airport managers; maintainers of this infrastructure; and design engineers and policy makers. Related and supporting work includes coordinated tropical cyclone research and development and improving space weather services. Tropical cyclones are clearly high-impact weather events for coastal urban areas and improved intensity forecasting is a high priority. The understanding of space weather effects on communications, navigation, security, health, and the electrical power grid continues to grow through continuing education and outreach efforts of the National Space Weather Program. The community is also more attuned to the social sciences aspects of the forecasting and warning system, building on the work of the OFCM exploration of tropical cyclone warnings in Mobile, Alabama, and Charleston, South Carolina, and the expanded activity in this area in National Science Foundation grants.

## Homeland Security

The homeland security element of urban meteorology addresses primarily the vectors of air and water in dispersion of accidental and deliberate releases of chemical, biological, nuclear, and radiological hazards. The urban environment by its nature places large numbers of people in a small area and this area is typically a road, rail, transit, water, pipeline, or air hub, or perhaps all six in the cases of major metropolitan areas. The transport of significant amounts of all variety of hazardous materials into or near urban areas increases the risk of accidental release as does the prevalence of industry often located in or near urban areas. The increased volume of hazardous materials stored, used, produced, or transiting urban areas also brings with it the threat of accidental release caused by weather conditions such as hurricanes, flooding, and tornadoes. Unfortunately, the higher concentration of people also provides a more lucrative target for terrorist activity because of the likelihood of more casualties and greater psychological and political impact. The flow of air and water in the urban environment is critical to responding effectively to either an accidental or deliberate release of hazardous materials.

Accurate diagnostic and predictive transport and diffusion modeling is difficult in the best circumstances and the urban environment adds even more complexity in observing, understanding, predicting, and responding to accidental and deliberate releases of hazardous chemicals, biological agents, and radiological particles. Meteorological conditions such as wind, temperature, cloud cover, and precipitation, combined with the effects of complex terrain dramatically alter the dispersion of these hazards and the resulting effects on the urban populace and infrastructure. Urban terrain includes a wide range of objects from bushes and trees, to houses, bridges, and skyscrapers, all varying in size from a few feet to hundreds of feet to thousands of feet, meaning one or a few observations of meteorological conditions in or near the area will be insufficient for accurate prediction. These features add extreme complexity to urban plume modeling, largely because of the challenge of accurately representing turbulent processes. In addition, the problem is often compounded by a lack of information on the hazard source—what was released, when, and how much. Furthermore, the lack of information on the exchange of indoor and outdoor air for every building in the area adds additional uncertainty in any prediction, particularly for determining effects on the populace.

Improving Products and Services for Homeland Security

Following the September 11, 2001, terrorist attacks, the interagency community under the OFCM's leadership assessed the state of the art among available dispersion models and decided on a core capability. They also established the Interagency Modeling and Atmospheric Assessment Center (IMAAC) to provide a coordinated first response to hazardous releases, and the OFCM led the development of an interagency dispersion model R&D plan to improve capability in light of the extensive limitations of the current generation of models. Although improvements have been made, much work remains to be done. In a June 2008 report, the GAO determined that first responders' ability to detect and model hazardous releases in urban areas is significantly limited. [6] Among their recommendations was a call for accelerated research and development to address plume model deficiencies and improve federal modeling and assessment capabilities, including improvements in meteorological information, plume models, and data sets with which to evaluate plume models.

In addition to improving the models, other actions underway may ultimately contribute to improved capability. Modeling for the urban environment requires complex data assimilation, an area of expertise already identified as critically short. The OFCM is leading an interagency effort to identify other critical skill shortages among the agencies to allow timely action to mitigate this and future shortfalls. In the systems area, MPAR can directly measure the three-dimensional wind field to provide a key input to prediction models and the Joint Urban Testbed project presents the opportunity to improve the overall process but, in particular, improve the availability and quality of meteorological and other observations in major metropolitan areas.

## Air and Water Quality

The air and water quality elements of urban meteorology are of widespread and constant concern for the health and economic vitality of the urban area. Unlike the severe weather and homeland security elements which may have very dramatic consequences but tend to be short in duration, air and water quality affects everyone all of the time. Pollutant loading is a concern in both areas, including the spectrum of chemical and particulate pollutants produced locally or carried into the area. These pollutants are generated from transportation, industry, energy production, building heating systems, and even wildland fires where smoke is carried into the area or changes in land cover in burned areas degrade water quality following precipitation and runoff. Predicting the dispersion of pollutants in the urban environment is similar to the plume modeling challenge identified in the homeland security section, but can be additionally complicated by the widespread, various, and persistent sources of pollution compared to the oftentimes point source of an accidental or deliberate release of hazardous chemicals or materials.

Air quality affects the health of the urban populace, particularly the at risk populations of the elderly, infants, and those with respiratory problems. Large metropolitan areas experiencing stagnant meteorological conditions or situated in certain topography often experience particularly severe episodes of poor air quality. Notable recent examples include the 2008 Olympic Games in Beijing, China, and calls for reduced outdoor activity because of wildfires in Northern California. China took unprecedented steps to reduce air pollution during the Games by closing factories and reducing vehicular traffic, leading to the best air quality in a decade and making the mountains north and west of the city visible from the city center. In the United States, wildland fires have been particularly severe in recent years, with records set for acreage burned in wildland fires in 2004, 2005, 2006, and 2007 [7] including the immediate San Diego, California, area in 2007. In June 2008, for example, poor air quality prompted officials to cancel outdoor activities in Northern California due to smoke from wildland fires.

The urban area and its built environment of impermeable pavements, structures, and roofs present an engineering challenge for the design of effective drainage systems, driving the need for climatological information for design and meteorological information for day-to-day management. Overtaxed drainage systems can lead to serious water quality problems and create health hazards when sewage treatment facilities are overwhelmed. Even systems providing adequate drainage can reduce water quality through untreated run-off of chemicals, particulates, and fertilizers from urban roadways, structures, and lawns.

Urban areas often encompass one or more rivers and heavy rains and sudden snow melt across wide areas, including rural areas upstream, can result in urban flooding as described above for the Seattle area. Another example of flooding that also raised concerns over water quality came in June 2008, when portions of the central United States experienced extensive river flooding across much of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin. Central Iowa and the city of Cedar Rapids were among the hardest hit areas, experiencing floodwaters contaminated with an unhealthy mix of sewage, farm and animal waste runoff, and petroleum products. Residents of Cedar Rapids who returned to their homes to inspect damage and salvage belongings had to wade through the ankle-deep contaminated floodwater, raising concerns about the availability of clean drinking water and skin exposure.

In addition to the negative health effects, various air and water pollutants accelerate corrosion of structures, vehicles, and equipment, adding to the infrastructure maintenance challenges for urban areas. Pollution can also degrade recreational opportunities, not just from a health perspective but from reduced visibility in scenic areas both inside and outside of the urban zone itself.

Water presents the additional problem of the adequacy of supply in addition to the quality of the water available. Drought conditions at various times and locations throughout the country have exacerbated existing conflict and created new conflict over water rights, management, and distribution. Changes in precipitation patterns across urban areas and their supplying watersheds as a result of changing climate can heighten tension as demand grows. The next major section will address climate variability and change in more detail.

Improving Products and Services for Air and Water Quality

Many of the same interagency efforts already described also support improving products and services for air and water quality, including phased array radar, weather information for surface transportation, dispersion modeling, and assessing and addressing hydrometeorological needs. MPAR can directly measure three-dimensional winds in and around the urban area, and improved transportation efficiency through more accurate forecasts and improved application of weather information can reduce the pollutant loading in and downstream from the urban area. As plume modeling improves to support homeland security, those advances will support improved modeling of pollutant dispersion, a better understanding of air and water quality, and potential steps to take to improve air and water quality. Finally, the hydrometeorology mini-workshops in the fall of 2008 began a coordinated approach to identify needs and set priorities to drive improvements in hydrometeorological products and services, not just for the urban environment but across the spectrum of environments and users.

## Climate Variability and Change

As the causes and effects of climate variability and change continue to be studied, towns and cities are beginning to prepare for and respond to extreme weather events which may increase in frequency and intensity with changes in climate. According to the U.S. Climate Change Science Program Synthesis and Assessment Product 3.3, *Weather and Climate Extremes in a Changing Climate*, published in June 2008 [8]:

> "In the future, with continued global warming, heat waves and heavy downpours are very likely to further increase in frequency and intensity. Substantial areas of North America are likely to have more frequent droughts of greater severity. Hurricane wind speeds, rainfall intensity, and storm surge levels are likely to increase. The strongest cold season storms are likely to become more frequent, with stronger winds and more extreme wave heights."

Extreme weather and weather-driven events such as heat waves, droughts, wildfires, heavy and persistent rainfall, and floods in urban areas pose risks to urban lives and infrastructure. Severe convective activity such as lightning, damaging winds, and tornadoes routinely threaten and occasionally cause major destruction in urban areas. In coastal areas, rising seas, warming waters, and hurricanes affect the economy, daily lives, and activities not only of urban populations but of the entire nation. The prospect of increased frequency and severity of these events and the new risk to urban areas with no previous experience in such problems has prompted growing concern among public officials. City leaders and other government officials are beginning to take notice and take action.

In New York City, New York, in 2008 the mayor formed a Climate Change Adaptation Task Force and the New York City Panel on Climate Change to develop adaptation strategies to protect the city's infrastructure. [9] The task force brought together city and state agencies, authorities, and private sector entities that operate, maintain, or control critical infrastructure and the Panel organized experts from academia and the legal, engineering, and insurance industries to provide advice to the task force.

As civic leaders at all levels begin to assess the risks associated with climate variability and change and make decisions about planning for adaptation or mitigation, they will need sound advice and the best information possible to support their decisions. The door is open for the federal agencies to begin eliciting specific needs, requirements, and priorities for climate products and services to support decision makers such as city leaders and the New York City Task Force. This decision support will be needed across a number of weather and climate areas, including wildland fires, flooding, severe local storms, water resources and drought, and tropical cyclones.

Changing Patterns of Wildland Fires

Wildfires increasingly infringe on urban areas as the urban boundary expands and blurs at the wildland-urban interface. Changing precipitation and temperature patterns, increasing drought, and accumulated fuel load are raising the risk of extensive fire, especially in the West. Wildland fires burned record acreage in 2004, 2005, 2006, and 2007 [7] and trends show a dramatic increase in fire activity over the last two decades. [10] This increase in activity has placed significant strain on firefighting and fire suppression budgets as well as the fire crews themselves. Climate variability and change can expand, shrink, or shift the areas at greatest risk, and the OFCM's national needs assessment for wildland fire weather showed that 83 percent of respondents rated fire and climate change important.

The interagency wildland fire weather community has completed a national needs assessment and in 2009 will be completing its assessment of current and planned capabilities, identifying gaps in meeting needs, and developing the framework to address the gaps through coordinated interagency activity. The results of this work will support improved wildland fire weather services to the benefit of the urban community and the nation overall. The need for climate information is clear and the potential payoff is high from reliable support to activities such as land use planning and planning and budgeting for firefighting and suppression activities at all levels of government.

Conveying Flood Risk to Leaders and the Public

The frequency and severity of flooding may also be changing and floods will continue to be a threat to urban areas. As illustrated earlier in this article, the recent catastrophic floods in the Midwest have shown the vulnerability of many cities. Flood predictions in these areas were characterized as historic flood events and forecasters for Burlington, Iowa, for example, called for the crest to be a 100- to 200-year flood, second only to the Great Flood of 1993 which was considered a 500-year flood event. However, such characterizations have drawn criticism because the region was struck for a second time since 1993 by a "once in a lifetime" flood. The widespread misunderstanding of 100-year and 500-year floods among the general public pointedly demonstrates the need for improved integration of the social sciences in the forecasting and warning process to deliver products and services that will be more clearly understood and acted upon as intended. This is applicable to both weather and climate products and services and may be even more important for climate because of its more probabilistic and statistical nature.

Localized High-Impact Weather – Implications for Infrastructure

A variable and changing climate can be expected to alter the patterns of severe convective activity such as lightning, damaging winds, and tornadoes that strike urban areas. During the summer of 2008, a powerful and fast-moving severe thunderstorm complex moved through Chicago, Illinois, causing baseball fans to seek shelter in the stadium concourse at Wrigley Field and passengers at O'Hare International Airport to evacuate to lower levels of the terminal. In all, 350 flights were canceled as the fast-moving storms passed through the area, generating effects felt throughout the country's airline and air traffic system. What climate products and services do public officials and the public need in the face of these potential changes? Where is the boundary between climate and a long-term weather forecast and does that matter to the user? Would an airline place enough confidence in a climate prediction to alter its flight schedules? These are just some of the challenging questions yet to be answered.

Water Resources, Water Quality, and Adapting to Drought

Climate variability and change will undoubtedly change the supply and quality of water in some if not many urban areas. Droughts of varying severity, coverage, and duration have real impact on urban areas as water supplies dwindle, water quality declines, fire danger grows in surrounding wildland areas, food shortages drive economic hardships and potentially health problems, energy needs change, and other direct and indirect effects alter the society and the economy. Drought rarely affects a single governmental jurisdiction alone and the likelihood of water-based conflict among local, state, tribal, and national governments and other stakeholders is high. Reliable long term estimates of drought conditions can at least bound the problem and reduce some conflict, but how much uncertainty can be tolerated? What level of confidence is needed in a climate product or service before it will be used as a basis for decisions and agreements with major impacts on large populations? Can intergovernmental agreements and infrastructure projects be flexible enough to change with differing and uncertain time scales of variability?

Changing Tropical Cyclone Threat

Storm surge, damaging winds, flooding, mass evacuations, and in-place sheltering will continue to pose significant challenges for urban emergency managers and city officials. Additional research is needed to understand changes in tropical cyclone activity as a result of climate variability and change, but the potential for increased frequency and severity is a source of concern among these managers and officials. And although coastal urban areas are at highest risk, urban areas well inland also face severe weather and flooding as the remnants of cyclones move across these areas. Predicting the track, intensity, structure, and effects of tropical cyclones remains a challenge and a focus today for coordinated interagency research and development. Tropical cyclones are one example of an area needing improved understanding of the physical processes and greater modeling capacity to be able to meaningfully assess the effects of climate variability and change on the tropical cyclone threat for a given urban area.

## Summary

More than two-thirds of the U.S. population resides in an urban area and urban areas present unique challenges for meteorological services and supporting research. This article presented a number of examples of high-impact, weather-related events in urban environments, highlighted some of the associated challenges, and described a number of interagency, coordinated activities underway to address the unique problems of urban meteorology. In 2004, the OFCM in its report, *Urban Meteorology: Meeting Weather Needs in the Urban Community*, identified five elements of primary interest: 1) severe weather; 2) homeland security; 3) air quality; 4) water quality; and 5) climate and this breakout served as the framework for this article.

Challenges in urban meteorology include improving observations and data collection, improving forecasts, integrating social sciences into the forecasting and warning process to deliver products and services that will be more clearly understood and acted upon as intended, and beginning to understand the effects of climate variability and change on the urban environment including beginning to define future climate products and services.

To address these challenges, the OFCM and its interagency partners are working together to improve capability in a number of areas. These include risk reduction for the Multifunction Phased Array Radar, Weather Information for Surface Transportation, tropical cyclone research and development, wildland fire weather needs, assessing hydrometeorology needs and identifying priorities, improving atmospheric dispersion models and establishing the Joint Urban Testbed, and incorporating social science aspects into services to obtain desired responses.

All of these efforts are interconnected, mutually supporting, and aimed at addressing the challenges of the urban environment and high-impact events in these unique areas. The overarching drive is to improve products and services to meet societal demand.

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# SECTION 2

# RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The tables in this section summarize budgetary information of the Federal government for fiscal years 2008 and 2009. The funds shown are used to provide meteorological services and associated supporting research that has as its immediate objective service improvement. Fiscal data are current as of the end of September 2008 and are subject to later changes. The data for Fiscal Year (FY) 2009 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 FY 2008 based on Congressional appropriations, the budget request for FY 2009, the percent change, and the individual agencies' percent of the total Federal funding for FY 2008 and FY 2009.

### DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 2009 is $45.4 million for operations and supporting research, representing a 9.7 percent decrease from the FY 2008 funding level. This decline was due to a reduction in funding for supporting research. USDA has requested $29.1 million for research and development programs, a $5.1 million decrease from 2008. The FY 2009 amount requested for meteorological operations is $16.3 million, up from $16.1 million in FY 2008. Operational activities include specialized weather observing networks such as the SNOTEL (SNOw pack TELemetry) system operated by the Natural Resources Conservation Service (NRCS) and the remote automated weather stations (RAWS) network managed by the Forest Service. The SNOTEL and RAWS networks provide cooperative data for NOAA's river forecast activities, irrigation water supply estimates, and Bureau of Land Management operations. The Forest Service is also the world leader in developing emissions factors from fires and modeling its dispersion. The USDA and the Department of Commerce (DOC) jointly operate a global agricultural weather and information center located in Washington, D.C. This Joint Agricultural Weather Facility operationally monitors global weather conditions and assesses the impacts of growing season weather on crop and livestock production prospects. This information keeps crop and livestock producers, farm organizations, agribusinesses, state and national farm policy-makers, government agencies, and foreign buyers of agricultural products apprised of worldwide weather-related developments and their effects on crops and livestock. Furthermore, tracking weather and crop developments in countries that are either major exporters or importers of agricultural commodities keeps the agricultural sector informed on potential competitors. USDA is also actively involved in drought monitoring efforts in concert with the National Drought Mitigation Center.

For supporting research, USDA funds research projects through the Cooperative State Research, Education and Extension Service (CSREES) that study the impact of climate and weather on food and fiber production. 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. Furthermore, the Agricultural Research Service (ARS) conducts research on how annual variation in weather adversely effects crop and animal production, hydrologic processes, the availability of water from watersheds, and the envi-

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

(Thousands of Dollars)

| | Operations | | | % of FY2009 | Supporting Research | | | % of FY2009 | Total | | | % of FY2008 | % of FY2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGENCY | FY2008 | FY2009 | %CHG | TOTAL | FY2008 | FY2009 | %CHG | TOTAL | FY2008 | FY2009 | %CHG | TOTAL | TOTAL |
| Agriculture | 16077 | 16335 | 1.6 | 0.5 | 34206 | 29063 | -15.0 | 2.3 | 50283 | 45398 | -9.7 | 1.2 | 1.0 |
| Commerce/NOAA(Subtot) | 1880870 | 2113708 | 12.4 | 66.1 | 105195 | 122798 | 16.7 | 9.5 | 1986065 | 2236506 | 12.6 | 47.5 | 49.8 |
| NWS | 893345 | 916743 | 2.6 | 28.7 | 17151 | 26234 | 53.0 | 2.0 | 910496 | 942977 | 3.6 | 21.8 | 21.0 |
| NESDIS*** | 927663 | 1129504 | 21.8 | 35.3 | 26459 | 28376 | 7.2 | 2.2 | 954122 | 1157880 | 21.4 | 22.8 | 25.8 |
| OAR | 0 | 0 | 0 | 0.0 | 52018 | 57515 | 10.6 | 4.5 | 52018 | 57515 | 10.6 | 1.2 | 1.3 |
| NOS | 25668 | 28314 | 10.3 | 0.9 | 500 | 500 | 0.0 | 0.0 | 26168 | 28814 | 10.1 | 0.6 | 0.6 |
| OMAO | 34194 | 39147 | 14.5 | 1.2 | 9067 | 10173 | 12.2 | 0.8 | 43261 | 49320 | 14.0 | 1.0 | 1.1 |
| Defense(Subtot) | 648568 | 625045 | -3.6 | 19.6 | 389801 | 357612 | -8.3 | 27.7 | 1038369 | 982657 | -5.4 | 24.9 | 21.9 |
| Air Force*** | 382535 | 389453 | 1.8 | 12.2 | 373484 | 336816 | -9.8 | 26.1 | 756019 | 726269 | -3.9 | 18.1 | 16.2 |
| DMSP** | 132964 | 119092 | -10.4 | 3.7 | 0 | 0 | 0 | 0.0 | 132964 | 119092 | -10.4 | 3.2 | 2.7 |
| Navy | 87370 | 70890 | -18.9 | 2.2 | 2518 | 9731 | 286.5 | 0.8 | 89888 | 80621 | -10.3 | 2.2 | 1.8 |
| Army | 45699 | 45610 | -0.2 | 1.4 | 13799 | 11065 | -19.8 | 0.9 | 59498 | 56675 | -4.7 | 1.4 | 1.3 |
| Homeland Security (Subtot) | 21540 | 23060 | 7.1 | 0.7 | 0 | 0 | 0.0 | 0.0 | 21540 | 23060 | 7.1 | 0.5 | 0.5 |
| USCG | 21540 | 23060 | 7.1 | 0.7 | 0 | 0 | 0.0 | 0.0 | 21540 | 23060 | 7.1 | 0.5 | 0.5 |
| Interior/BLM | 2400 | 2400 | 0.0 | 0.1 | 0 | 0 | 0.0 | 0.0 | 2400 | 2400 | 0.0 | 0.1 | 0.1 |
| Transportation(Subtot) | 381186 | 408033 | 7.0 | 12.8 | 32514 | 38252 | 17.6 | 3.0 | 413700 | 446285 | 7.9 | 9.9 | 9.9 |
| FAA | 381186 | 408033 | 7.0 | 12.8 | 28314 | 34052 | 20.3 | 2.6 | 409500 | 442085 | 8.0 | 9.8 | 9.9 |
| FRA | 0 | 0 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| FHWA | 0 | 0 | 0.0 | 0.0 | 4200 | 4200 | 0.0 | 0.3 | 4200 | 4200 | 0.0 | 0.1 | 0.1 |
| EPA | 0 | 0 | 0.0 | 0.0 | 9000 | 9000 | 0.0 | 0.7 | 9000 | 9000 | 0.0 | 0.2 | 0.2 |
| NASA | 7199 | 7497 | 4.1 | 0.2 | 648866 | 733212 | 13.0 | 56.8 | 656065 | 740709 | 12.9 | 15.7 | 16.5 |
| NRC | 120 | 500 | 316.7 | 0.0 | 0 | 0 | 0.0 | 0.0 | 120 | 500 | 316.7 | 0.0 | 0.0 |
| TOTAL | 2957960 | 3196578 | 8.1 | 100.0 | 1219582 | 1289937 | 5.8 | 100.0 | 4177542 | 4486515 | 7.4 | 100.0 | 100.0 |
| % of FY TOTAL | 70.8% | 71.2% | | | 29.2% | 28.8% | | | 100.0% | 100.0% | | | |

*The FY 2008 funding reflects Congressionally appropriated funds; the FY 2009 funding reflects the amount requested in the President's FY 2009 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.

***NESDIS and Air Force budget numbers include the DOC and DOD shares of the NPOESS budget, respectively.

ronmental and economic sustainability of agricultural enterprises.

## DEPARTMENT OF COMMERCE (DOC)

The DOC/NOAA budget request for FY 2009 is 2.24 billion (Table 2.1, line 2) for operations and supporting research, representing a 12.6 percent increase from the FY 2008 funding level. The overall DOC increase is mainly the result of increases in NESDIS requested funding. Of the $2.24 billion in DOC/NOAA funding, the vast majority funds operations ($2.11 billion) with the rest ($122.8 million) going to supporting research.

### NOAA's NATIONAL WEATHER SERVICE (NWS)

The National Weather Service (NWS) provides weather, hydrologic, 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 for use by other government agencies, the private sector, the public, and the global community.

The FY 2009 President's Budget Request supports the funding and program requirements necessary to address established NOAA strategic goals and sets NWS on a path to achieve the following objectives: produce and deliver effective and timely forecasts and warnings that can be trusted in order to protect lives and property; use cutting-edge technologies to provide the best services possible in a cost-effective manner; and improve economic benefits by the timely and accurate dissemination of weather, water, and climate information.

The NWS requested a total of $943.0 million and 4,640 Full Time Equivalent (FTE) employees to support continued and enhanced operations. The total includes $9.1 million for Adjustments to Base (ATB), and Net Program Changes of $50.2 million. The changes are summarized at the subactivity level below and, to be concise, do not include descriptions below $1.0 million. Descriptions of each request by line item are located in the NOAA FY 2009 Technical Budget.

NWS requested $9.1 million and 0 FTE to fund ATB across all activity accounts. With this increase, program totals will fund the estimated FY 2009 Federal pay raise and annualize the FY 2008 pay raise through the remainder of the calendar year. Program totals will provide inflationary increases for non-labor activities, including service contracts, utilities, field office lease payments, and rent charges from the General Services Administration.

NWS also requests transfers between appropriations or line offices including:

- $3.0 million is transferred from Local Warnings & Forecasts to Complete & Sustain NOAA All Hazards Weather Radio resulting in a net 0 change for NWS.
- $5.9 million is transferred from the U.S. Weather Research Program (USWRP) in NWS to the Office of Atmospheric Research (OAR).

### NWS PROGRAM CHANGE HIGHLIGHTS FOR FY 2009:

NWS requested a net increase of $32.5 million from FY 2008 and 1 FTE for a total request of $943.0 million and 4,640 FTE.

Operations, Research, and Facilities (ORF)

A net increase of $31.6 million and 1 FTE above the base is requested in ORF for a total of $828.1 million and 4,609 FTE.

Operations and Research (O&R)

A net increase of $28.8 million and 1 FTE above the base is requested in the Operations and Research subactivity, for a total of $729.8 million and 4,421 FTE.

Local Warnings and Forecasts

$14.5 million and 0 FTE in net increases above the base, for a total of $662.6 million and 4,114 FTE, requested under the Local Warnings and Forecasts line item of the Operations and Research subactivity.

- TAO Tropical Moored Buoy Technology Refresh (+0 FTE and +$1.1 million): NOAA requests an increase of 0 FTE and $1.1 million to replace obsolete components of the Nation's foremost climate observing system. Total funding required to replace obsolete components for the 55 buoys in this array is $6.6 million. This effort will be accomplished over a six year period beginning in FY 2008.

- Florida/Caribbean Hurricane Data Buoy (Operation and Maintenance) (+0 FTE and +$3.0 million): NOAA requested an increase of 0 FTEs and $3.0 million for a total of $4.4 million to operate and maintain 15 weather data buoys (eight buoys funded under the FY 2006 Hurricane Supplemental Appropriation and seven funded by the FY 2005 Hurricane Supplemental Appropriation) for enhanced real time hurricane data observations and storm monitoring in the Caribbean, Gulf of Mexico, and the Atlantic Ocean to support the NOAA hurricane warning and forecast mission.
- Ocean Sensor Operation and Maintenance (+0 FTE and +$1.4 million): NOAA requested an increase of 0 FTEs and $1.4 million for ongoing operation and maintenance of the Congressionally mandated ocean instrumentation which was funded and installed by National Ocean Service "Convert Weather Buoys Initiative." These sensors augment fixed and buoy observational sites. In keeping with NOAA's commitment to increased interoperability and cost effective approach to oceanographic observing, the NOS Convert Weather Buoys Initiative augments existing National Weather Service buoys with oceanographic sensors. This national network of weather observing buoys has been augmented with ocean sensors to measure directional waves and wave heights, and ocean current, temperature, and salinity profiles.
- Ongoing Operations and Maintenance for Systems/equipment Purchased to Meet Requirements of Hurricane Supplemental (+0 FTE and + $1.2 million): NOAA requested 0 FTE and $1.2 million to pay on-going operations and maintenance costs for Incident Meteorologist equipment, software support, and communications, ASOS and NWR backup power units, and backup communications for coastal Weather Forecast Offices and Weather Radars.

Central Forecast Guidance

Net increases above the base of $14.3 million and 1 FTE, for a total of $67.2 million and 307 FTEs, are requested under the Central Forecast Guidance line item of the Operations and Research subactivity.

- Hurricane/Environmental Modeling Improvements (+1 FTE and +$14.3 million): Through the President's Budget Amendment, NOAA requested a total increase of 1 FTE and $14.3 million for a total of $14.3 million in FY 2009 to sustain the Administration's commitment to significantly accelerate the improvement in hurricane track and intensity forecasts. Funds are required to increase the research and development necessary to accelerate the improvement in the NOAA Hurricane Forecast System (NHFS), transition and test new capabilities in operations, and operate and maintain the expanded NHFS (including coupled global, hurricane, ocean, wave, and storm surge models). The goal of the hurricane forecast improvement program is to increase accuracy of hurricane track and intensity forecasts, provide for objective forecast guidance and substantially improve the capability to forecast associated storm surge.

System Operations & Maintenance (O&M)

NWS requested $98.3 million and 188 FTE, which is an increase of $2.8 million and 0 FTE to support the ongoing operations and maintenance of major NWS observation and processing systems. These systems include the Next Generation Weather Radar (NEXRAD), Automated Surface Observing System (ASOS), Advanced Weather Interactive Processing System (AWIPS)/NOAAPort, and the NWS Telecommunications Gateway System (NWSTG) and its backup. NWS currently operates 121 NEXRAD Systems that utilize Doppler technology and hydrometeorological processing to provide weather radar data for tornado and thunderstorm warnings, air safety, flash flood warnings, and water resource information. The 312 NWS ASOS sites provide reliable 24-hour per day surface weather observations. AWIPS provides an integrated system to display all hydrometeorological data at NWS field offices. The system acquires and processes data from modernized sensors and local sources, provides computational and display functions, provides interactive communication systems, and disseminates weather and flood warnings and forecasts in a rapid and highly reliable manner. The NWSTG and its backup systems serve as the Nation's hub for the collection and distribution of weather data and products. NWSTG and backup provide national and global real-time exchange services using an automated communication system to collect and distribute a wide range of environmental data such as observations, analyses, forecasts, and warning products.

Procurement, Acquisition, and Construction

A net increase of $18.6 million and 0 FTE above the base is requested in Procurement, Acquisition, and Construction, for a total of $114.9 million and 31 FTE.

System Acquisition

A net increase of $18.4 million and 0 FTE above the base is requested in the System Acquisition subactivity, for a total of $88.3 million and 31 FTE.

- Weather Radio Improvement Project (+0 FTE and +$2.9 million): NOAA requested an increase of $2.9 million and 0 FTE for a total of $5.7 million to fund the effort to modernize the NOAA Weather Radio All Hazards (NWR) network, replacing obsolete unsupportable broadcast equipment and taking advantage of satellite technology to allow for point to multi-point communications capability and network redundancy and meet Federal Emergency Management Agency (FEMA) needs. This increase will allow the NWS to deploy the NWR Broadcast Management System (BMS). The BMS is a replacement for the Console Replacement System (CRS). Also included is the development of a system that will integrate the NOAA Weather Wire Service (NWWS) into a consolidated network with the BMS. Currently, the contract to maintain the NWWS expires in FY 2009. The current CRS is at its end of life and cannot be supported at the current level due to parts obsolescence. The CRS is a main component of NWR that converts text warning messages into digital voice. This conversion provides the voice warning messages that are broadcast over the NWR to alert the public. It is critical that we address this issue now in order to avert potential outages that might affect our ability to disseminate warnings to the public.
- NOAA Profiler Network (NPN) Conversion (+0 FTE and +$4.8 million): NOAA requests an increase of 0 FTE and $4.8 million for a total of $9.7 million to replace transmitters that interfere with Search and Rescue Satellites and to conduct technology refresh of the 20-year-old network. This increase continues the approved multi-year investment. The Wind Profilers, vertical looking radars installed in 1988, are used as input for numerical weather models that predict clouds, precipitation, and temperature. The data also provide important indicators of where severe weather such as tornadoes and winter storms may form and is used for issuing aviation advisories and wildfire predictions. Research has shown Wind Profiler data improves accuracy and lead times for tornado, severe thunderstorm, flash flood, and winter storm warnings. Thirty-two of the 37 wind profilers are using an experimental transmitter frequency of 404 megahertz (MHz) issued by the National Telecommunications and Information Administration (NTIA). NTIA has given the 404 MHz frequency to search and rescue satellites (SARSAT) and granted the NPN permanent use of 449 MHz. In addition, the European Space Agency began launching a constellation of 30 satellites called Galileo in FY 2006, which also have a SAR capability with an operating frequency of 404 MHz. Thirty operational 404 MHz wind profilers require their transmitters to be converted from 404 to 449 MHz. In addition to the 30 operational sites using 404MHz, there are two 404 MHz wind profilers at the National Reconditioning Center and National Weather Service Training Center (used for testing and training). There are also five wind profilers in the NPN that operate at the non-interfering 449 MHz frequency: three in Alaska, one in Syracuse, New York, and one in Platteville, Colorado. In 2009, the NPN will have been installed for 20 years without any technology refresh during its life cycle. Therefore a second priority is a technology refresh for the entire 37 wind profiler network. This refresh includes replacing the 5 existing 449 MHz profilers, replacing the network's VAX system computers and re-hosting the software on a LINUX platform; improving the telecommunications network, replacing site modems, data collection modems,

and uninterruptible power systems; and providing a major overhaul of site shelters, facility electric distribution, replacement of Radio Acoustic Sounding System components, and upgraded satellite communications equipment.

- AWIPS Technology Infusion (+0 FTE and +$6.6 million): NOAA requests an increase of 0 FTE and $6.6 million for a total of $19.1 million to invest in new forecaster workstation technology and to develop capabilities necessary to meet the growing demands of society for improved high impact forecast and warning services. These services include on site incident support; provision of services using new dissemination media with the latest graphical display formats; provision of probability information; improved service backup; and forecast collaboration. Evolving NWS services will require capitalizing on new technology and infusing new science and techniques. This will not be possible without a technology infusion of the Advanced Weather Interactive Process System (AWIPS), the key workstation forecasters use at Weather Forecast Offices to integrate, interpret multiple sources of observational and model data, and generate forecast and warning products.
- Weather and Climate Supercomputing (+0 FTE and +$3.0 million): Through the President's Budget Amendment, NOAA requests an increase of 0 FTE and $3.0 million for a total of 0 FTE and $22.1 million for its Weather and Climate Supercomputing program to accelerate planned NOAA hurricane forecasting system improvements in both hurricane track and hurricane intensity forecasts. Funds are required to procure additional High Performance Computing (HPC) necessary to provide higher resolution numerical weather prediction modeling to support the acceleration of improved intensity forecasts.

Construction

NOAA requests $14.1 million to complete the NOAA Center for Weather and Climate Prediction (NCWCP) and $12.5 million for Weather Forecast Office (WFO) construction funding to NOAA facilities to support NOAA facility planning requirements for at total of $26.6 million. Construction subactivity does not have FY 2009 program changes.

NOAA's NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICES (NESDIS)

Proposed funding for FY 2009 includes a decrease in the Polar-Orbiting Satellite Program (POES) of $48.9 million, a net increase in the Geostationary Satellite Program (GOES) of $235.2 million, and a request to fund the National Polar-orbiting Operational Environmental Satellite System (NPOESS) at the Nunn-McCurdy Certified program funding level. 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 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 for the POES program is decreasing as it approaches the end of its production cycle with one remaining satellite, NOAA N prime, to be launched. The GOES request includes a decrease of $7.0 million for the GOES-N series of satellites, and an increase of $242.2 million for the next generation GOES-R series.

The converged NOAA and Department of Defense (DOD) polar orbiting system (NPOESS) will replace the current NOAA series and the DOD Defense Meteorological Satellite Program (DMSP). A total of $288.0 million is included in the budget request to maintain basic mission satellite 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.

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. Included in the budget request is $53.6 million for the NOAA Data Centers and Information Services sub-activity base operating funds.

NOAA's NATIONAL OCEAN SERVICE (NOS)

Funding provided through the FY 2009 budget will allow for additional expansion of the PORTS program, including continued implementation of the second generation of the NOS CO-OPS advanced data quality control program, the Continuous Operational Real-time Monitoring System (CORMS AI), as well as the ongoing operation of the Ocean Systems Test and Evaluation Program (OSTEP), which is a development program for bringing new sensor technology into operations. The FY 2008 budget has allowed for sufficient support to operate the National Water Level Observation Network (NWLON) and for continued growth of the Physical Oceanographic Real-Time System (PORTS®). Both the NWLON and PORTS programs have subsets of operational water level stations with meteorological sensors installed for various partners and users, including the NWS.

In FY 2008, NOS received funding to upgrade and enhance as many as 45 NWLON with new meteorological sensors. The NWLON has traditionally been an oceanographic observing system; however, NWLON technology allows multiple other sensors to be added, including meteorological sensors such as wind speed/direction/gusts, air temperature, and barometric pressure. These observations provide a significant data source for improving and verifying marine weather forecasts and warnings. Actual verification data for special marine warnings (WFO Sterling) shows a 10% increase in the probability of detection and a ten minute increase in warning lead times, due in part to an increase in marine observations. Navigation data users require a complete picture of their operating environment to make the best safety and efficiency decisions, and local meteorological data is a part of that picture. Optimization of existing observing infrastructure is a cost-effective alternative to establishing new platforms. The additional meteorological data will also improve the accuracy of NWS forecasts of storm surge, marine wind speed, and marine wave heights for use by both the marine navigation and coastal communities when extreme weather events occur. The real-time information can be used by emergency responders to make sound decisions based upon which coastal areas are flooding, which evacuation routes are still viable, and other situations requiring a good understanding of the current state of the physical environment.

In FY 2008, NOS received funds to construct additional new NWLON stations to fill critical observation gaps identified by NWS. Initial sites were along the Gulf Coast. Also, NOS has been hardening additional existing Gulf Coast NWLON stations by constructing elevated strengthened platforms and relocating equipment to them.

NOS operational nowcast/forecast modeling activities are expanding and rely upon NWS Eta model data streams as hydrodynamic model drivers. NOS, in cooperation with NWS and OAR in have developed an operational nowcast/forecast capability for the Great Lakes.

NOAA's OFFICE OF OCEAN AND ATMOSPHERIC RESEARCH (OAR)

Requested FY 2009 funding for Weather and Air Quality Research (W&AQR) is $57.5 million–a net increase of $5.5 million or 10.6 percent more than the FY 2008 appropriation. Increases of $10.4 million consist of funds to: partially cover inflationary cost increases within base programs ($0.8 million), transfer management of the U.S. Weather Research Program from NWS back to OAR ($5.5 million), enhance NOAA's new Unmanned Aircraft Systems (UAS) Program ($3.0 million), and conduct research to improve operational weather forecasts ($1.0 million). Proposed decreases of $4.9 million result from terminating unrequested funding added by Congress to W&AQR in FY 2008, including funds for: the Northern Gulf Institute ($1.8 million), Science Center for Teaching, Outreach and Research on Meteorology (STORM) ($0.6 million), Advanced Radar Technologies Feasibility Study ($0.1 million), Tornado & Hurricane Operations & Research ($0.8 million), Wind Hazards Reduction Program ($0.6 million), Coastal & Inland Hurricane Monitoring & Protection Program ($0.6 million), San Joaquin Valley Ozone Study ($0.1 million), and Coastal Weather Monitoring for Catastrophic Events ($0.3 million).

NOAA'S OFFICE OF MARINE AND AVIATION OPERATIONS (OMAO)

OMAO supports meteorological activities by collection of related data from ships and aircraft. The FY 2009 President's Budget includes an increase of $2.0 million from the FY 2008 appropriation for OMAO that are related to aircraft-supported meteorological data collection.

## DEPARTMENT OF DEFENSE (DOD)

The total DOD budget request for FY 2009, including NPOESS funding, is $982.7 million which represents a funding decrease of 5.4 percent from FY 2008. Specific highlights for each of the military departments are described below:

### U.S. AIR FORCE (USAF)

USAF resources for meteorological support fall into several categories: general operations, investment and research, Defense Meteorological Satellite Program (DMSP), and National Polar-orbiting Operational Environmental Satellite System (NPOESS) supporting research. The total Air Force operations and research funding for FY 2009, including DMSP and NPOESS, is $845.4 million (table 2.1, 10th column, rows 9 & 10).

#### Operations

The operations support portion of Air Force weather's FY 2009 budget is $348.6 million (table 2.2, 2nd column, lines 9 & 10) and funds day-to-day environmental support to the Department of Defense, including DMSP operations, the Active and Reserve Components of the Air Force and Army, nine unified commands, and other agencies as directed by the Chief of Staff of the Air Force. Over 4,100 Active and Reserve Component military and civilian personnel (table 2.6) conduct these activities at more than 275 locations worldwide. Approximately 85 percent of personnel specialize in weather; the remainder includes communications, computer, administrative, and logistics specialists.

DMSP operations are a critical source of space-borne meteorological data for the military services and other high-priority DOD programs. DMSP environmental data is also distributed to the National Weather Service, National Environmental Satellite, Data, and Information Service, the Navy's Fleet Numerical Meteorology and Oceanography Center, the Naval Oceanographic Office, and Air Force Weather Agency according to interagency agreements.

The Air Force's total projected FY 2009 outlays for DMSP are $119.1 million (table 2.1, column 2). This funding provides for the operations and sustainment of the on-orbit constellation, as well as integration, test, and flight hardware modifications and replacement to maximize performance and longevity of the satellites that remain to be launched. DMSP satellites are acquired and launched by the Air Force and funding to operate the satellites on-orbit is transferred by the Air Force to National Oceanic and Atmospheric Administration each year (Table 2.7).

#### Supporting Research

The total AF research budget for FY 2009 is 336.8 million (table 2.1, column 6) which is comprised of general AF weather and NPOESS funding supporting Research, Development, Test and Evaluation (RDTE) efforts.

Air Force weather's FY 2009 budget request for general RDTE is $47.3 million (not shown in tables). This amount is an increase in funding over FY 2008 as a result of efforts related to NPOESS infrastructure needs and other transformational initiatives that recapitalize legacy systems, build robust environmental digital data bases, and disseminate data streams to DOD and coalition C2 systems in a machine-to-machine (M2M)/net-centric era. As part of AF Smart Operations 21st Century (AFSO 21), Air Force weather is investing in modernized environmental prediction technologies and global information grid technologies that enhance automation and save manpower. Also, Air Force weather is investing in the following efforts in FY 2009 and beyond: Joint Environmental Toolkit (JET), Weather Research and Forecast (WRF) model, modernizing space weather capabilities, Cloud Depiction and Forecasting System (CDFS) II improvements, advanced MARK IVB use, Tactical Decision Aids, Weather Data Analysis (WDA), and Ensemble Prediction System (EPS). The goals of these efforts are to provide accurate and relevant weather information to warfighters at all levels of operations quicker and more consistently than ever before, within the decision cycle in a manner that facilitates exploiting the current and forecasted weather conditions. Specifically, JET will eliminate redundancies and/or inefficiencies and ultimately extend, consolidate and/or replace the Operational Weather Squadron (OWS) Production System-Phase II (OPS II), the Joint Weather Impacts System (JWIS), the New-Tactical Forecast System (N-TFS), and the weather effects decision aids portion of the Integrated Meteorological System (IMETS). WRF advances, such as with the Land Surface Model and WRF coupling, will improve forecasting performance in the low levels of the atmosphere. This will allow AF weather forces to provide better forecasts for low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also allows for assessment of trafficability for ground forces. Collaboration with U.S. and Allied government and civilian agencies, and modernizing ground-based sensing will result in a robust space sensing capability. Improving CDFS techniques by doubling the resolution, integrating geosynchronous METSATs into the cloud analysis, using a new cloud interpretation scheme, and blending numerical weather prediction with forecast cloud advection techniques will ensure the AF continues as a center of excellence in cloud forecasting. MARK IVB data integration into cloud models will be expanded. Tactical Decision Aids (TDAs) provide warfighters an automated way to "visualize" environmental impacts on operations. These tools which continue to be integrated into C2 systems (e.g., mission planning systems) include Target Acquisition Weapons Software (TAWS), Infrared Target Scene Simulation (IRTSS), and Tri-Service Integrated Weather Effects Decision Aid (T-IWEDA). WDA will provide many of the behind-the-scene tools at the weather production centers necessary for enabling JET to provide decision-quality products and information to warfighters. EPS output will help AF weather personnel to provide better forecasts for the warfighter with increased confidence, particularly at the tactical level. While these all work synergistically to provide warfighters a quantum leap in capability, JET is the most visible piece to decision-makers. JET will exploit data contained in the Virtual Joint Meteorological Oceanographic (METOC) Database via common-user-communications, integrate with joint and coalition command and control and mission planning systems, and provide the machine-to-machine data exchange for assimilating METOC and C4ISR data to meet operational and tactical mission planning and execution requirements.

The FY 2009 DOD R&D budget for NPOESS is $289.5 million (not shown in table) for the continued development of system architecture, technology, critical sensors, and algorithms. These dollars are applied to both the NPOESS Preparatory Project run by NASA and the NPOESS program being acquired by a tri-agency Integrated Program Office.

## U.S. NAVY

The U.S. Navy FY 2009 budget total request for meteorological programs is $80.6 million (table 2.1, column 10) made up of $70.9 million for operations and $9.7 million for supporting research.

### Naval Oceanography Program (NOP)

NOP remains a unique, world-class program. Focusing support in the environmentally complex coastal/littoral regions around the globe, Naval METOC personnel (Navy and Marine Corps) are required to provide intelligence preparation of the environment (IPE) for operational decisionmakers by assessing the impact of atmospheric and ocean phenomena on platforms, sensors and weapon systems. Additionally, Navy and Marine Corp METOC personnel provide for safe flight and navigation in support of naval, joint, and combined forces operating throughout the world's oceans. This is done with a cadre of highly trained military and civilian personnel, educated in both sciences and warfighting applications. By teaming with and leveraging the efforts of other agencies and activities, the NOP meets these challenges in a most cost effective manner, providing a full spectrum of products and services with only a small percentage of the Federal weather budget. The NOP is required to provide comprehensive and integrated weather and ocean support worldwide. The Oceanographer/Navigator of the Navy sponsors programs in four closely related disciplines - meteorology, oceanography, geospatial information services, and precise time and astrometry. All are used to protect ships, aircraft, fighting personnel, 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.

### Littoral Battlespace Sensing, Fusion, and Integration (LBSF&I)

LBSF&I is the Department of the Navy's principal Intelligence Preparation of the Environment approach for atmospheric and oceanographic data collection, processing, and data/product dissemination to users. LBSF&I will facilitate better tactical decision making by enabling a system of networked sensors to allow information sharing through interoperability with naval and joint networks and information systems. It addresses critical gaps with respect to environmental data fidelity (in time and space) shown to play a critical role in force disposition and force posture in current and future naval missions. LBSF&I is a critical persistent IPE technology, a key component of the Naval Oceanography Battlespace on Demand frame-work, and supports the Battlespace Awareness Joint Capability Area through 2025.

Operational Support

Naval METOC support starts with sensing the battlespace without being adversely affected by physical environmental and culminates with weapons arriving on target and enabling personnel to operate 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 METOC products and services. As naval operations in the littoral increase, Naval METOC support is directed towards providing on-scene capabilities to personnel that directly furnish environmental data for sensor, weapon system, and personnel planning and employment. These on-scene capabilities are key elements for enabling the war-fighters to take advantage of the natural environment as part of battlespace management. Owing to the crucial interrelationship of the ocean and the atmosphere, Naval METOC requires various oceanographic products to provide the requisite meteorological services. In addition to aviation and maritime METOC support, Navy and Marine Corps METOC teams provide 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.

Systems Acquisition

Naval METOC systems acquisition is accomplished through the Program Executive Office for Command, Control, Communication, Computes and Intelligence and Space (C4I and Space) in San Diego, California.

Research and Development (R&D)

Naval METOC R&D are cooperatively sponsored by the Oceanographer/Navigator of the Navy and the Chief of Naval Research. Naval 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. Projects initiated by the Navy and Marine Corps, under sponsorship of the Oceanographer/Navigator of the Navy, transition from engineering development to operational naval systems. Such efforts include advances in Naval METOC forecasting capabilities, 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, weapons systems, and platform performance. To realize the opportunities and navigate the challenges ahead, the Department of Navy must have a clear vision of how they will organize, integrate, and transform. "Sea Power 21" is that vision. It will align our efforts, accelerate our progress, and realize the potential of our people. Support to naval operations is provided under the direction of the Commander, Naval Meteorology and Oceanography Command (CNMOC) located at the Stennis Space Center, Mississippi and the Marine Corps advocate for METOC, the Deputy Commandant for Aviation, at Headquarters Marine Corps, Washington, D.C. With the addition of the Naval Oceanography Operations Command the NOP optimizes warfighting recourses, supports safe operations and enhances dominance of the battlespace through superior understanding and exploitation of the environment. The Naval METOC community work closely with research developers and operational forces to ensure that naval and joint force commanders will always have the most accurate, timely, and geo-referenced METOC information available for successful operations.

U.S. ARMY

The U.S. Army estimates a requirement for $45.6 million for operational support and $11.1 million for research and development in FY 2009. The total amount of money budgeted for weather support is estimated because the costs to support USAF weather personnel are normally part of the overall G-3 or G-2 operating budget at the Army Commands (ACOMs), Army Service Component Commands (ASCCs), Corps, Division, or Brigade level and are not assigned a specific program element or budget line. Additionally, programs or projects that are assigned a budget line are often part of a larger project's budget and the exact amount of monies spent on meteorological related activities cannot be independently verified. The budget numbers presented in this report represent the best estimate of the Army regarding meteorological related spending over the period of the report. Operational support for FY 2009 is projected to remain approximately even with FY 2008 expenditures and research is estimated to decrease about $2.7 million from the previous year. Staffing levels remain stable for FY 2009. The $64M supplemental funding for the AN/TMQ-52 Meteorological Measuring Set – Profiler (MMS-P) programmed in last year's report has not materialized, and the budget data have been adjusted appropriately.

Army monies for meteorology are spent in four main areas: support to U.S. Army Artillery Meteorology Sections (ARTYMET), support to USAF weather personnel at Army locations, research and development related to the Army mission, and the development, production, and maintenance of Army meteorological systems.

ASCCs with Staff Weather Officers and their associated weather personnel provide the same support and services to these forces that they normally provide to Army personnel. This support includes the use of facilities to house weather operations, medical support, access to training facilities, office supplies, utilities and maintenance for weather facilities, vehicles and tactical equipment, and funding for official travel. Eighth U.S. Army, U.S. Army Europe, U.S. Army Pacific, Forces Command, and Training and Doctrine Command (TRADOC) all provide this support to AF weather personnel assigned at the ACOM level and below.

Major portions of ACOMs and ASCCs meteorological expenditures support Artillery Meteorology Sections, also known as ARTYMET Teams, or Met Sections. Wind data are then passed to the U.S. Army Artillery units for firing computations. Artillery Met Sections range in size from six personnel at a Light Division to twelve personnel at a Heavy Division. Eighth U. S. Army, U.S. Army Europe, U.S. Army Pacific, Forces Command, and the Army National Guard all support Met Sections. Training and Doctrine Command supports twenty-four military and civilian personnel at the U.S. Army Artillery School (USAFAS) at Fort Sill, OK. These personnel train ARTYMET Teams on the use of the AN/TMQ-41 Meteorological Measuring Set and the AN/TMQ-52 Meteorological Measuring Set - Profiler. ARTYMET team structures will be changing over the next few years to support the Army's new modularity concept. No attempt has been made to convert the part-time Army National Guard ARTYMET Teams into full time equivalents.

Headquarters, Department of the Army, Deputy Chief of Staff, G-2 employs two full-time meteorologists for development of meteorological policy; coordination of meteorological support within the Department of the Army and with other Department of Defense and Federal agencies and organizations; Department of the Army Policy concerning weather; environmental services, and oceanographic support to the Army (less those environmental services functions assigned to the Corps of Engineers); and Department of the Army policy concerning peacetime weather support. The USAF provides one full time Staff Weather Officer to serve as a liaison between the AF and the Army Staff.

Forces Command (FORSCOM) will program approximately $300,000 in FY09 for meteorological operations support. FORSCOM and subordinate units do not budget directly for Air Force Weather teams, but provide some support for them on an as-needed basis from general operations and maintenance budgets. FY08 budget numbers for artillery were carried forward as an estimate for FY09 as artillery budget numbers were not available for this report.

TRADOC programmed approximately $2.6M for FY08 for meteorological services and plans to fund $3.1M for FY09. The majority of these TRADOC funds, a total of $2.4M, are planned for operations support related to training development, instructor/support personnel, logistics (expendable supplies), and repair costs on artillery meteorological systems at the USAFAS.

As a result of the previous two years (FY06-07) of investment in creating training development products, there were no training development costs in FY08. Training development costs will increase to approximately $100K in FY09. This cost increase is due to a technical manual's rewrite and a software upgrade. Training development cost is estimated to increase from $100K FY09 to $300K FY10. Expected future cost for training development are classroom modernization, equipment upgrade and innovative training devices.

Instructor/Support personnel costs (~$1.71M) in FY08 are the result of USAFAS at Fort Sill, OK employing 30 personnel to conduct training using the AN/TMQ-41 Meteorological Measuring Set (MMS) and the AN/TMQ-52A Meteorological Measuring Set-Profiler (MMS-P). Additionally, this cost includes the requirement to fund five contract instructors to support the increased number of soldiers dictated by the Army's modular design. This is an increase from FY07 by ~$283K due to the addition of three instructors (two contractors and one enlisted soldier). Instructor/Support personnel costs are expected to increase to (~$2,2M) in FY09 as a result of USAFAS at Fort Sill, OK, employing 31 personnel to conduct training using the AN/TMQ-41 Meteorological Measuring Set (MMS) and the AN/TMQ-52A Meteorological Measuring Set-Profiler (MMS-P).

Logistics/supply costs ($160K) for FY08 are a result of the increased number of soldiers trained over the year. We expect logistics/supply costs to increase to (~$190.5K) in FY 09 due to supplies for meteorological sounding equipment to support live fire and training at Fort Sill.

Repair costs ($260K) in FY08 will decrease for AN/TMQ-41 due to the depletion of parts. Costs associated with AN/TMQ-52A Meteorological Measuring Set-Profiler (MMS-P) will increase due maintaining and operating a second MMS-Profiler system. Overall cost is expected to decrease from $260K to $160K in FY09.

TRADOC also programmed $76K in FY08 to fund a TRADOC Capabilities Manager (TCM) position for the Army's Integrated Meteorological System (IMETS). This position falls under the TRADOC Program Integration Office – All Source Analysis System (TPIO-ASAS) at the US Army Intelligence Center and School (USAICS) at Ft Huachuca, AZ. TPIO-ASAS has programmed $78K for this same position in FY09. Additionally, in FY09, Fort Huachuca has programmed an additional $149K to fund for a Chief of the Army Weather Proponent Office, a newly created office and position at Fort Huachuca.

TRADOC transferred $153K in FY08 to Air Combat Command for the maintenance and service of five Army Automated Surface Observing Sensor (ASOS) systems and two Army pole-mounted Tactical Meteorological Observing Systems (TMOS) at Fort Rucker, AL. Contract maintenance and service costs have been programmed to increase to ~$160K in FY09.

Army Materiel Command (AMC) will fund a variety of activities for FY09, most of which fall into research and development and systems acquisition. There has been no programmed Integrated Meteorological System (IMETS) funding line since FY05; however, there have been 3 sources of funding available to the IMETS Project Office - DA restored Other Procurement Army (OPA) funding via Program Manager Intelligence Fusion, Distributed Common Ground System - Army (DCGS-A) OPA, and DCGS-A R&D. FY08 OPA funds were used for the continued production, fielding, and support of IMETS and new development for DCGS-A Weather Services. Northrop Grumman Corporation (Tacoma/Lakewood, WA) is the primary contractor supporting the OPA effort. R&D funding supports the development of new capabilities, the testing & integration of IMETS capabilities into the DCGS-A, and to integrate the Air Force Joint Environmental Toolkit (JET) software into the IMETS/DCGS-A. The Army Research Laboratory (ARL) and the New Mexico State University (NMSU) Physical Sciences Laboratory (PSL) partner on IMETS development and technology insertion efforts. IMETS Project Office closed on 30 September 2007 to become DCGS-A Weather Services. Future funding for DCGS-A Weather Services (IMETS) will come from DCGS-A program funding. Maintenance and support for the fielded IMETS, until the systems are replaced by DCGS-A, is an unresolved issue. Future development of DCGS-A Weather Services will include a joint effort with PD Digital Topographic Support Systems (DTSS) to build a combined weather/terrain spin-out (TWSO) system as a risk-reduction step towards the full production DCGS-A Weather Services. The TWSO will combine the architecture of DCGS-A Ver 4 with the AF joint environmental toolkit (JET) software module to provide a net-centric weather capability replacing all Program of Record (POR) IMETS systems by FY12. The anticipated $64M supplemental funding for the FY08 Profiler Program was not realized as of this writing and has been backed out of both the FY08 and FY09 budget projections.

The FY08 budget for meteorological support in Eighth U.S. Army decreased significantly from FY07 primarily due to the completed acquisition and fielding of 20 automated weather systems (includes 4-year warranty), using $1.825M in FY07 funds (HQDA funded Eighth Army initiative). FY08 budget activity of $190,000 provided steady state operational support for meteorological services by Army ARTYMET ($322,000) and Air Force ($40,000) units. The FY09 Air Force budget is projected to increase to $85,000 to account for increased TDY costs to support Army units, and a planned computer lifecycle upgrade. Meanwhile, the ARTYMET budget will increase to $356,000 to account for operating costs for an additional Army ARTYMET AN/TMQ-52 Profiler System that 210th Fires Brigade expects to field in FY09.

The USARPAC budget for Army Meteorological support will slightly increase for FY08/09. The 25ID(L), supported by the 25th Air Support Operations Squadron (ASOS), received an increased estimate for FY08 IMETS-V and IMETS-L sustainment funds. In addition, a new MTOE for USARPAC's Operational Command Post authorizes an IMETS-L system for USARPAC–which will require sustainment funding. ARTYMET personnel levels remain the same, but costs increased due to the 2.2% pay raise for military personnel.

Space and Missile Defense Command (SMDC) supports several meteorological missions. SMDC has funding designated for the operational support at the High Energy Laser Systems Test Facility (HELSTF) for contract services to operate and maintain the instrumentation, equipment, and facilities to support the atmospheric sciences/meteorological mission. SMDC also operates contract support services to operate the Ronald Reagan Missile Defense Test Site for operations support and special weather programs.

For the USARIEM research program in FY08, there was an increase in expenditures on weather-related research. It is anticipated that FY09 funding for weather-related research efforts at the U.S. Army Research Institute of Environmental Medicine (USARIEM) will decrease relative to the FY 08 Level.

## DEPARTMENT OF HOMELAND SECURITY (DHS)

U.S. COAST GUARD (USCG)

All of USCG's funding for meteorological programs is for operations support. For FY 2009, the requested funding level is $23.1 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. Coast Guard efforts in meteorological operations and services have not changed significantly during recent years.

## DEPARTMENT OF INTERIOR (DOI)

The total DOI/BLM weather funding request for FY 2009 is $2.4 million. This amount is for meteorological operations and the support of the Bureau of Land Management (BLM) Remote Automatic Weather Station (RAWS) program. An additional $1.1 million is recovered each year through reimbursable accounts with participating agencies. Normal operations and maintenance of the RAWS program is approximately $900,000 yearly. (This includes travel, transportation, utilities, services, supplies, equipment and other non-labor costs.)

Support of the RAWS program by the BLM will continue in FY 2009, as part of the Wildland Fire Agencies' participation in Fire Weather activities and the National Fire Danger Rating System (NFDRS). In addition to upgrading and maintaining fixed-site RAWS, the BLM will address increasing demand for the use of mobile units for both fire and non-fire applications. Continued efforts will be made to achieve an optimum balance of fixed and mobile RAWS resources and support. Cooperation between DOI agencies and the USDA Forest Service regarding combined meteorological requirements for the National Wildland Fire support functions is ongoing. Interagency RAWS activity is coordinated at a working group level with representation by all participants, and will continue to implement NFDRS standards to ensure the protection of both life and property from wildland fires.

## DEPARTMENT OF TRANSPORTATION (DOT)

The DOT total budget request for FY2009 is $446.3 million by far the most going to the Federal Aviation Administration (FAA). The meteorological programs for the FAA and the Federal Highway Administration are described below.

### FEDERAL AVIATION ADMINISTRATION (FAA)

For 2009, FAA requested a total $442.1 million for the Aviation Weather Programs including acquisition of new systems, operations and support, and supporting research.

The actual funding for aviation weather in FY 2008 was $409.5 million. For FY 2009, FAA requested $32.6 million more representing an 8 percent increase in total funding. The changes are comprised of:

An increase in systems acquisitions of $31.6 million to $123.3 million, reflecting new and increased programs for NextGen (see below);

A decrease in operations support of $1.1 million to $279.1 million reflecting a decrease in federal personnel in the automated flight service station operations as a result of the A-76 contract award; and

An increase for aviation weather research of $5.7 million to a total of $34.1 million (Table 2.5).

The funding changes reflect major initiatives in the aviation weather programs in support of the Next Generation (NextGen) National Air Transport System to bring increased and enhanced automation to the collection of weather observations from remote sensors, to the dissemination of weather products, graphics and decision making information available for use by the air traffic facilities, pilots, the aviation industry and general aviation users.

The Aviation Weather Research Program will continue research into understanding the geophysical phenomena in the atmosphere and around airports that present hazardous conditions for aircraft operations. Among these hazards are in-flight icing, turbulence, visibility, ceiling, convective activity, tornadoes, etc. Additional work will be done to improve models, develop better graphics for decision making information, and understanding the impacts of space weather on aviation.

### FEDERAL HIGHWAY ADMINISTRATION (FHWA)

The total FHWA request for surface transportation weather programs in FY 2009 is $4.2 million, all of which will be used for supporting research.

In 1999, the FHWA began documenting road weather data requirements, and this has served as the basis for the majority of work and research in this area. This work, some of which is described below, includes addressing the technical aspects of the road transportation system (including environmental data collection, processing and dissemination) as well as the institutional challenges associated with system implementation.

Addressing these institutional challenges has helped foster coordination within state and local Departments of Transportation (DOTs) as well as across the transportation and meteorological communities. With regard to technical areas of interest, data collection efforts have included increased coverage of atmospheric and road condition observations, as well as incorporation of 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 road weather information. This road weather information will enable more effective decision making, leading to a safer and more efficient surface transportation system.

A U.S. DOT initiative entitled Clarus will develop, demonstrate and support deployment of a nationwide surface transportation weather observing and forecasting system, and ultimately foster nationwide data sharing capabilities. Clarus will allow agencies to share quality-checked environmental data, ultimately improving forecasts and value-added weather information products, as well as supporting anytime, anywhere road weather information for all road and transit users and operators.

A multi-year effort has been undertaken by the FHWA in cooperation with six national laboratories to prototype and field test advanced decision support tools for winter maintenance managers. The Maintenance Decision Support System (MDSS) prototype is a decision support tool that integrates relevant road weather forecasts, coded rules of practice for winter maintenance operations, and maintenance resource data to provide managers with customized road treatment recommendations. The first functional MDSS prototype was demonstrated in Iowa in early 2003 and during the winter season of 2003-2004. During the winter season of 2004-2005, the MDSS prototype was successfully deployed in a third demonstration in Colorado and in early 2006; this product was declared a "market ready technology." By 2007, 21 state transportation agencies were using or developing MDSS tools. The current focus of the MDSS project is to continue to build on current outreach program activities such as sponsoring annual stakeholder meetings, conducting product "Road Shows" and Demonstration Showcases, facilitating technology transfers to the private sector, providing assistance to public agencies in writing request for proposals, and participating in informational conferences. The project team also plans to conduct a series of benefit/cost analyses to produce "hard" financial data that can be used to support investing in such a system and exploring the potential of expanding the functionality of MDSS beyond winter maintenance to include such activities as non-winter road maintenance, construction, and traffic management.

In 2006, the FHWA completed a study on how Traffic Management Centers (TMCs) around the country integrate road weather information into their operations. The FHWA documented the types of road weather information received by TMCs, the means of information delivery, how information needs change as the severity of a weather event increases, and how that information impacts traffic management decisions. Based on the findings of this study, the FHWA initiated a project in 2007 to develop a self-assessment guide to help TMCs evaluate their weather information integration needs and assist them in developing weather integration plans. The FHWA is also conducting analyses and developing models to quantify the impacts of various weather events on driver behavior and highway traffic, working to incorporate weather and pavement condition data into traffic analysis tools, as well as investigating a variety of weather-responsive traffic management strategies such as changing traffic signal timing in response to weather and posting weather-related messages on variable message signs. These efforts will help FHWA advance the state-of-the-practice in weather-responsive traffic management.

The efforts described above, as well as future activities captured in the Road Weather Management program plan will be examined within the context of two key reports published in early 2004 and described below.

In 2002, the FHWA asked the National Research Council (NRC) Board of Atmospheric Sciences & Climate to examine what needs to be done from the research, development, and technology transfer perspectives to improve the production and delivery of weather-related information for the nation's road-ways. In March 2004, the NRC released a report, Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services, which recommended the creation of a focused, national road weather research program led by FHWA that brings together the transportation and meteorological communities, identifies research priorities, and implements new scientific and technological advances. The NRC recommendations included making better use of existing road weather information and technologies to increase capabilities for transportation research, establishing a nationwide real-time road weather observing system, developing observing capabilities to assess the accuracy of road weather forecasts, improving environmental sensor technologies, and developing new means to effectively communicate road weather information to a wide range of users. Most, if not all of these recommendations, have been incorporated into the roadmap that is being used to guide the activities of the Road Weather Management Program.

To strengthen relationships between the meteorological and surface transportation communities, the FHWA Road Weather Management Program and the American Meteorological Society (AMS) co-sponsored a Policy Forum on Weather and Highways in November 2003. The objective was to discuss the provision of weather information to improve highway operations, the development of strategies to effectively respond to weather information, and the policy issues related to effective application of weather services to the management of the nation's highway system. The forum brought together nearly 100 representatives from public, private, and academic sectors at federal, state, and local levels. The report resulting from the forum, Weather and Highways: Report of a Policy Forum, contained several recommendations including long-term congressional funding to develop a national road weather research, development, and applications program; close coordination of federal and state DOTs to improve the safety and efficiency of highways during adverse weather; and establishing a national road weather data collection, processing, and dissemination system. Based upon the recommendations that were made in the AMS and NRC reports, the FHWA and the National Oceanic and Atmospheric Administration (NOAA) signed a memorandum of understanding (MOU) in July of 2005 to enable the two agencies to work together to achieve shared goals for a safer and more efficient surface transportation system. By working together, these two agencies will be able to take advantage of each other's investments and expertise, as well as promote improved surface transportation weather training, products, and services. A near-term goal of this partnership will be the introduction of new products, services and training to improve the application of weather information to surface transportation operations.

## ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of the EPA's funding of meteorological and air quality programs is for supporting research. The anticipated funding level in FY 2009 for directed meteorological research is $9.0 million which is the same funding level as in FY 2008.

Continued attention is being paid to the effects of airborne toxins and fine particulate matter on human health, on the effect of climate change on air quality, and the impact on ecosystems. In addition, to promote excellence in environmental science and engineering, EPA established a national fellowship program and substantially increased its support for investigator-initiated research grants. The 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 the same in FY 2009 as in FY 2008.

This program will fund research in areas including ecological assessment, air quality, environmental fate and treatment of toxins and hazardous wastes, effects of global climate change on air quality, and exploratory research. The portion of these grants that will be awarded for meteorological research during FY 2009 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $9.0 million listed above for directed meteorological research.

In collaboration with NOAA, EPA is continuing its development and evaluation of air quality models for air pollutants on all temporal and spatial scales as mandated by the Clean Air Act as amended in 1990. Research will focus on urban, mesoscale, regional, and multimedia models, which will be used to develop air pollution control strategies, human and ecosystem exposure assessments, and air quality forecasting. There will be increased emphasis placed on meteorological research into regional and urban formation and transport of air contaminants in support of the revisions to the National Ambient Air Quality Standards and homeland security. 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)**

For FY 2009, NASA requests a total of almost $740.7 million. Nearly all of NASA funding in meteorology is for supporting research. The NASA Earth Science Division (ESD) budget consists of seven programs: Earth Systematic Missions, Earth Science Pathfinder, Research, Applied Sciences, Multi-Mission Operations, Technology and Education and Outreach. The funding levels represent the estimated meteorology share of the supporting research and analysis programs within the ESD budget. The Earth Systematic Missions program contributes to the Systems Development line in the budget request; the other six programs contribute to the Research and Development line.

**NUCLEAR REGULATORY COMMISSION (NRC)**

The NRC planned expenditure of $500,000 in FY 2009 is for meteorological operations to continue technical assistance for the analysis of atmospheric dispersion for routine and postulated accidental releases from nuclear facilities; for preparation of guidance on meteorological issues in licensing actions; and for the review of proposed sites for possible construction of new nuclear power plants.

The meteorological support program in the NRC is focused primarily on analyzing and utilizing meteorological data in atmospheric transport and dispersion models. These models provide insight on plume pathways in the near- and far-fields for building wake and dispersion characteristics to perform dose calculations on postulated releases to the environment. Meteorological information is used as input to the probabilistic safety assessment, the assessment of the radiological impacts of routine releases from normal operations, the assessment of other (non-radiological) hazards that may impact safe operation of the facility, and the assessment of design or operational changes proposed for the facility.

Additionally, after a hiatus of some 25 years, the nuclear power industry has expressed an interest in seeking approvals for new nuclear power plants. Numerous early site permit, combined license, and design certification applications have been received and are currently under review. These reviews will also consider regional climatology and local meteorology. In addition to its internal review activities, the NRC may seek assistance from other Federal agencies to support its safety reviews.

## 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.

In FY 2009, total Operational Costs requested are $3.19 billion with a total of $1.78 billion for Operations Support, $1.37 billion for Systems Acquisition, and $42.1 million for Special Programs.

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

For FY 2009, agencies will obligate a total of $1.29 billion in Supporting Research funds in the following manner: $589.0 million to research and development and $700.4 million to Systems Development.

## TABLE 2.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

| AGENCY | Operations Support FY2008 | Operations Support FY2009 | Systems Acquisition FY2008 | Systems Acquisition FY2009 | Special Programs FY2008 | Special Programs FY2009 | Total FY2008 | Total FY2009 | Total %CHG | % of FY2009 TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 16077 | 16335 | 0 | 0 | 0 | 0 | 16077 | 16335 | 1.6 | 0.5 |
| Commerce/NOAA(Subtot) | 991717 | 1003949 | 843671 | 1073979 | 45482 | 35780 | 1880870 | 2113708 | 12.4 | 66.1 |
| NWS | 790781 | 810298 | 67430 | 79841 | 35134 | 26604 | 893345 | 916743 | 2.6 | 28.7 |
| NESDIS*** | 152516 | 136916 | 775147 | 992588 | 0 | 0 | 927663 | 1129504 | 21.8 | 35.3 |
| OAR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| NOS | 25668 | 28314 | 0 | 0 | 0 | 0 | 25668 | 28314 | 10.3 | 0.9 |
| OMAO | 22752 | 28421 | 1094 | 1550 | 10348 | 9176 | 34194 | 39147 | 14.5 | 1.2 |
| Defense(Subtot) | 463116 | 450526 | 184801 | 173853 | 651 | 666 | 648568 | 625045 | -3.6 | 19.6 |
| Air Force*** | 328530 | 329323 | 54005 | 60130 | 0 | 0 | 382535 | 389453 | 1.8 | 12.2 |
| DMSP* | 17125 | 19304 | 115839 | 99788 | 0 | 0 | 132964 | 119092 | -10.4 | 3.7 |
| Navy | 85623 | 69472 | 1747 | 1418 | 0 | 0 | 87370 | 70890 | -18.9 | 2.2 |
| Army | 31838 | 32427 | 13210 | 12517 | 651 | 666 | 45699 | 45610 | -0.2 | 1.4 |
| Homeland Security (Subtot) | 21540 | 23060 | 0 | 0 | 0 | 0 | 21540 | 23060 | 7.1 | 0.7 |
| USCG | 21540 | 23060 | 0 | 0 | 0 | 0 | 21540 | 23060 | 7.1 | 0.7 |
| Interior/BLM | 2400 | 2400 | | | | | 2400 | 2400 | 0.0 | 0.1 |
| Transportation(Subtot) | 280170 | 279089 | 91738 | 123308 | 9278 | 5636 | 381186 | 408033 | 7.0 | 12.8 |
| FAA | 280170 | 279089 | 91738 | 123308 | 9278 | 5636 | 381186 | 408033 | 7.0 | 12.8 |
| FRA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| FHWA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| EPA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| NASA | 7199 | 7497 | 0 | 0 | 0 | 0 | 7199 | 7497 | 4.1 | 0.2 |
| NRC | 120 | 500 | 0 | 0 | 0 | 0 | 120 | 500 | 316.7 | 0.0 |
| TOTAL | 1782339 | 1783356 | 1120210 | 1371140 | 55411 | 42082 | 2957960 | 3196578 | 8.1 | 100.0 |
| % of FY TOTAL | 60.3% | 55.8% | 37.9% | 42.9% | 1.9% | 1.3% | 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.

***NESDIS and Air Force budget numbers also include the DOC and DOD shares of the NPOESS budget, respectively.

## TABLE 2.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

| | Research & Development | | Systems Development | | Special Programs | | Total | | | % of FY2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| AGENCY | FY2008 | FY2009 | FY2008 | FY2009 | FY2008 | FY2009 | FY2008 | FY2009 | %CHG | TOTAL |
| Agriculture | 34206 | 29063 | 0 | 0 | 0 | 0 | 34206 | 29063 | -15.0 | 2.3 |
| Commerce/NOAA(Subtot) | 101826 | 113086 | 2869 | 9212 | 500 | 500 | 105195 | 122798 | 16.7 | 9.5 |
| NWS | 15201 | 17822 | 1950 | 8412 | 0 | 0 | 17151 | 26234 | 53.0 | 2.0 |
| NESDIS | 26459 | 28376 | 0 | 0 | 0 | 0 | 26459 | 28376 | 7.2 | 2.2 |
| OAR | 51099 | 56715 | 919 | 800 | 0 | 0 | 52018 | 57515 | 10.6 | 4.5 |
| NOS | 0 | 0 | 0 | 0 | 500 | 500 | 500 | 500 | 0.0 | 0.0 |
| OMAO | 9067 | 10173 | 0 | 0 | 0 | 0 | 9067 | 10173 | 12.2 | 0.8 |
| Defense(Subtot) | 30075 | 37765 | 359726 | 319847 | 0 | 0 | 389801 | 357612 | -8.3 | 27.7 |
| Air Force*** | 13758 | 16969 | 359726 | 319847 | 0 | 0 | 373484 | 336816 | -9.8 | 26.1 |
| DMSP* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| Navy | 2518 | 9731 | 0 | 0 | 0 | 0 | 2518 | 9731 | 286.5 | 0.8 |
| Army | 13799 | 11065 | 0 | 0 | 0 | 0 | 13799 | 11065 | -19.8 | 0.9 |
| Homeland Security (Subtot) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| USCG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| Interior/BLM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| Transportation(Subtot) | 32514 | 38252 | 0 | 0 | 0 | 0 | 32514 | 38252 | 17.6 | 3.0 |
| FAA | 28314 | 34052 | 0 | 0 | 0 | 0 | 28314 | 34052 | 20.3 | 2.6 |
| FRA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| FHWA | 4200 | 4200 | 0 | 0 | 0 | 0 | 4200 | 4200 | 0.0 | 0.3 |
| EPA | 9000 | 9000 | 0 | 0 | 0 | 0 | 9000 | 9000 | 0.0 | 0.7 |
| NASA | 326335 | 361883 | 322531 | 371329 | 0 | 0 | 648866 | 733212 | 13.0 | 56.8 |
| NRC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 |
| TOTAL | 533956 | 589049 | 685126 | 700388 | 500 | 500 | 1219582 | 1289937 | 5.8 | 100.0 |
| % of FY TOTAL | 43.8% | 45.7% | 56.2% | 54.3% | 0.0% | 0.0% | 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.

***Air Force budget numbers also include the DOD share of the NPOESS budget

# 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 FY 2009 operational funds: basic meteorology services receiving 63.1 percent; aviation 14.0 percent; marine 3.9 percent; agriculture/ forestry 0.6 percent; general military services 17.8 percent; and other specialized services accounting for 0.6 percent.

Table 2.5 shows the distribution of supporting research funds among the services with basic meteorology receiving 10.3 percent, aviation 2.7 percent, marine 0.8 percent, agriculture and forestry 2.3 percent, general military 26.1 percent, and the remaining 57.9 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.

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

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

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

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

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

## TABLE 2.4 AGENCY OPERATIONAL COSTS, BY SERVICE

(Thousands of Dollars)

| AGENCY | Basic Meteorology FY2008 | Basic Meteorology FY2009 | Aviation FY2008 | Aviation FY2009 | Marine FY2008 | Marine FY2009 | Agriculture & Forestry FY2008 | Agriculture & Forestry FY2009 | General Military FY2008 | General Military FY2009 | Other FY2008 | Other FY2009 | Total FY2008 | Total FY2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 0 | 0 | 0 | 0 | 0 | 0 | 16077 | 16335 | 0 | 0 | 0 | 0 | 16077 | 16335 |
| Commerce/NOAA(Subtot) | 1772031 | 2003774 | 17622 | 18678 | 80869 | 82080 | 0 | 0 | 0 | 0 | 10348 | 9176 | 1880870 | 2113708 |
| NWS | 821616 | 845849 | 16528 | 17128 | 55201 | 53766 | 0 | 0 | 0 | 0 | 0 | 0 | 893345 | 916743 |
| NESDIS*** | 927663 | 1129504 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 927663 | 1129504 |
| OAR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NOS | 0 | 0 | 0 | 0 | 25668 | 28314 | 0 | 0 | 0 | 0 | 0 | 0 | 25668 | 28314 |
| OMAO | 22752 | 28421 | 1094 | 1550 | 0 | 0 | 0 | 0 | 0 | 0 | 10348 | 9176 | 34194 | 39147 |
| Defense(Subtot) | 14853 | 12051 | 26211 | 21267 | 25337 | 20558 | 0 | 0 | 577798 | 567624 | 4369 | 3545 | 648568 | 625045 |
| Air Force*** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 382535 | 389453 | 0 | 0 | 382535 | 389453 |
| DMSP* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 132964 | 119092 | 0 | 0 | 132964 | 119092 |
| Navy | 14853 | 12051 | 26211 | 21267 | 25337 | 20558 | 0 | 0 | 16600 | 13469 | 4369 | 3545 | 87370 | 70890 |
| Army | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45699 | 45610 | 0 | 0 | 45699 | 45610 |
| Homeland Security (Subtot) | 0 | 0 | 0 | 0 | 21540 | 23060 | 0 | 0 | 0 | 0 | 0 | 0 | 21540 | 23060 |
| USCG | 0 | 0 | 0 | 0 | 21540 | 23060 | 0 | 0 | 0 | 0 | 0 | 0 | 21540 | 23060 |
| Interior/BLM | 0 | 0 | 0 | 0 | 0 | 0 | 2400 | 2400 | 0 | 0 | 0 | 0 | 2400 | 2400 |
| Transportation(Subtot) | 0 | 0 | 381186 | 408033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 381186 | 408033 |
| FAA | 0 | 0 | 381186 | 408033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 381186 | 408033 |
| FRA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FHWA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| EPA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NASA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7199 | 7497 | 7199 | 7497 |
| NRC | 120 | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 120 | 500 |
| TOTAL | 1787004 | 2016325 | 425019 | 447978 | 127746 | 125698 | 18477 | 18735 | 577798 | 567624 | 21916 | 20218 | 2957960 | 3196578 |
| % of FY TOTAL | 60.4% | 63.1% | 14.4% | 14.0% | 4.3% | 3.9% | 0.6% | 0.6% | 19.5% | 17.8% | 0.7% | 0.6% | 100.0% | 100.0% |

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

***NESDIS and Air Force budget numbers also include the DOC and DOD share of the NPOESS budget, respectively.

## TABLE 2.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE

(Thousands of Dollars)

| AGENCY | Basic Meteorology FY2008 | Basic Meteorology FY2009 | Aviation FY2008 | Aviation FY2009 | Marine FY2008 | Marine FY2009 | Agriculture & Forestry FY2008 | Agriculture & Forestry FY2009 | General Military FY2008 | General Military FY2009 | Other FY2008 | Other FY2009 | Total FY2008 | Total FY2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 0 | 0 | 0 | 0 | 0 | 0 | 34206 | 29063 | 0 | 0 | 0 | 0 | 34206 | 29063 |
| Commerce/NOAA(Subtot) | 104169 | 121798 | 526 | 500 | 500 | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 105195 | 122798 |
| NWS | 17151 | 26234 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17151 | 26234 |
| NESDIS | 26459 | 28376 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26459 | 28376 |
| OAR | 51492 | 57015 | 526 | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 52018 | 57515 |
| NOS | 0 | 0 | 0 | 0 | 500 | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 500 | 500 |
| OMAO | 9067 | 10173 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9067 | 10173.3 |
| Defense(Subtot) | 13378 | 10741 | 0 | 0 | 2518 | 9731 | 0 | 0 | 373905 | 337140 | 0 | 0 | 389801 | 357612 |
| Air Force*** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 373484 | 336816 | 0 | 0 | 373484 | 336816 |
| DMSP* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Navy | 0 | 0 | 0 | 0 | 2518 | 9731 | 0 | 0 | 0 | 0 | 0 | 0 | 2518 | 9731 |
| Army | 13378 | 10741 | 0 | 0 | 0 | 0 | 0 | 0 | 421 | 324 | 0 | 0 | 13799 | 11065 |
| Homeland Security (Subtot) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USCG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Interior/BLM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Transportation(Subtot) | 0 | 0 | 28314 | 34052 | 0 | 0 | 0 | 0 | 0 | 0 | 4200 | 4200 | 32514 | 38252 |
| FAA | 0 | 0 | 28314 | 34052 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28314 | 34052 |
| FRA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FHWA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4200 | 4200 | 4200 | 4200 |
| EPA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9000 | 9000 | 9000 | 9000 |
| NASA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 648866 | 733212 | 648866 | 733212 |
| NRC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 117547 | 132539 | 28840 | 34552 | 3018 | 10231 | 34206 | 29063 | 373905 | 337140 | 662066 | 746412 | 1219582 | 1289937 |
| % of FY TOTAL | 9.6% | 10.3% | 2.4% | 2.7% | 0.2% | 0.8% | 2.8% | 2.3% | 30.7% | 26.1% | 54.3% | 57.9% | 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.

***Air Force budget numbers also include the DOD share of the NPOESS budget

# PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 2.6 depicts agency staff resources in meteorological operations. The total agency staff resources requested for FY 2009 is 11,286. This total represents a decrease of almost one percent from FY 2008. FAA's significant decrease in federal personnel from previous reports reflects completion of the phase down of federal flight service briefers as private contract personnel assumed briefing duties.

**TABLE 2.6 PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS**

(Units are Full time Equivalent Staff Years)*

| AGENCY | FY2008 | FY 2009 | %CHG | % of FY 2009 TOTAL |
|---|---|---|---|---|
| Agriculture | 130 | 132 | 1.5 | 1.2 |
| Commerce/NOAA (sub-total) | 5790 | 5791 | 0.0 | 51.3 |
| NWS | 4639 | 4640 | 0.0 | 41.1 |
| NESDIS (sub-total) | 889 | 889 | 0.0 | 7.9 |
| NESDIS | 831 | 831 | 0.0 | 7.4 |
| Reimbursed | 58 | 58 | 0.0 | 0.5 |
| OAR | 32 | 32 | 0.0 | 0.3 |
| NOS | 119 | 119 | 0.0 | 1.1 |
| OMAO | 111 | 111 | 0.0 | 1.0 |
| Defense(Subtotal) | 5044 | 4935 | -2.2 | 43.7 |
| Air Force(Subtotal) | 4261 | 4171 | -2.1 | 37.0 |
| AFW | 4142 | 4052 | -2.2 | 35.9 |
| DMSP | 119 | 119 | 0.0 | 1.1 |
| Navy | 413 | 399 | -3.4 | 3.5 |
| Army | 370 | 365 | -1.4 | 3.2 |
| Homeland Security-USCG | 108 | 108 | 0.0 | 1.0 |
| Interior/BLM(Subtotal) | 28 | 28 | 0.0 | 0.2 |
| Interior | 26 | 26 | 0.0 | 0.2 |
| Reimbursed** | 2 | 2 | 0.0 | 0.0 |
| Transportation(Subtotal) | 239 | 248 | 3.8 | 2.2 |
| FHWA | 4 | 4 | 0.0 | 0.0 |
| FAA | 235 | 244 | 3.8 | 2.2 |
| EPA | 0 | 0 | 0.0 | 0.0 |
| NASA | 42.1 | 42.7 | 0.0 | 0.4 |
| NRC | 2 | 2 | 0.0 | 0.0 |
| TOTAL | 11383 | 11286 | -0.8 | 99.0 |

** "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 2008. Agencies routinely enter into reimbursable agreements when they determine that one agency can provide the activity more 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.

**TABLE 2.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH**

| Agency Funds Transferred from: | Agency Funds Transferred to: | FY 2008 Funds ($K) Estimated or Planned: Operations | Supporting Research |
|---|---|---|---|
| USDA/Forest Service | NOAA | 10 | |
| DoD/Air Force | NOAA (for DMSP) | 11500 | |
| | DOC/NOAA/NWS | | 200 |
| | DOC/NOAA/NWS | 5332 | |
| | DOC/NOAA/NWS | | 138 |
| | DOC/NOAA/NWS | 440 | |
| | DOC/NOAA/NWS | 710 | |
| | OFCM | 140 | |
| | OFCM | 30 | |
| | DOC/NOAA/NESOIS/IPO (for DMSP) | 232 | |
| | USGS (Dept of Interior) | 450 | |
| | NASA | 220 | |
| | DOC/NOAA/SEC | 258 | |
| | NSF/UCAR | | 772 |
| | NSF/NCAR | | 2526 |
| | NSF/NCAR | | 710 |
| | NSF/NCAR | | 475 |
| | NASA | | 630 |
| | OPM | 15 | |
| | GSA | 125 | |
| | NOAA | 103 | |
| DoD/Army | COE (CW) to NWS | 570 | |
| | COE (CW) to USGS | 534 | |
| | Air Combat Command (ACC) | 78 | |
| | Air Combat Command (ACC) | 78 | |
| | ARO to NSF | | 11 |
| DoD/Navy | DOC | 81 | |
| | DOC | 189 | |
| NASA | DoD/USAF/45th Space Wing | 1505 | |
| | DoD/USAF/Edwards AFB | 105 | |
| | DOC/NOAA/NDBC | 103 | |
| | DOC/NOAA/SMG | 1807 | |
| FAA | DOC/NOAA (equipment) | 39400 | |
| | DOC/NOAA (instructors) | 1101 | |

# FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

Table 2.8 shows the number of facilities/locations or platforms at which the federal agencies carry out or supervise the taking of various types of meteorological observations. As of August 2008, the Army does not use upper-air rocket sensors anymore.

**TABLE 2.8 FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS**

| TYPE OF OBSERVATION by AGENCY | | No. of 2008 Locations |
|---|---|---|
| **Surface, land** | | |
| Commerce (all types) | | 841 |
| Air Force (U.S. & Overseas) | | 162 |
| Navy (U.S. & Overseas) | | 68 |
| Marine Corps (U.S. & Overseas) | | 13 |
| Army (U.S. & Overseas) | | 24 |
| Transportation (FAA Contract Wx Obsg Stn) | | 133 |
| Transportation (FAA Auto Wx Obsg Stn) | | 168 |
| Transportation (FAA Auto Sfc Obsg Sys, fielded) | | 580 |
| Transportation (FHWA-Road Wx Obsg Stn) | | 2017 |
| Homeland Security (USCG Coastal) | | 50 |
| Interior | | 470 |
| Agriculture | | 1886 |
| NASA (all types) | | 46 |
| | Sub-total | 6458 |
| **Surface, marine** | | |
| Commerce (SEAS-equipped ships) | | 622 |
| Commerce (Coastal-Marine Autom Network) | | 56 |
| Commerce (NOAA/NOS/PORTS) | | 18 |
| Commerce (PORTS only meteorological stations | | 50 |
| Commerce (Buoys--moored) | | 98 |
| Commerce (Buoys--drifting) | | 21 |
| Commerce (Buoys--large navigation) | | 10 |
| Commerce (Water-level gauges) | | 200 |
| Commerce (Water-level gauges with meteorology sensors | | 116 |
| Navy (Ships with met personnel) | | 29 |
| Navy (Ships without met personnel) | | 251 |
| Homeland Security (USCG Cutters) | | 252 |
| NASA (Buoys - moored) | | 2 |
| | Sub-total | 1725 |
| **Upper air, balloon** | | |
| Commerce (U.S.) | | 102 |
| Commerce (Foreign, Cooperative) | | 22 |
| Air Force, Fixed (U.S. & Overseas) | | 12 |
| Air Force, Mobile | | 15 |
| Army, Fixed (U.S. & Overseas) | | 18 |
| Army, Mobile (U.S. and Overseas) | | 85 |
| Navy, Fixed (U.S. & Overseas) | | 0 |
| Navy, Mobile(U.S. & Overseas) | | 10 |
| Navy, Ships | | 29 |
| Marine Corps, Mobile | | 10 |
| NASA (U.S. and Overseas) | | 4 |
| | Sub-total | 307 |
| **Atmospheric Profilers** | | |
| Air Force (Eastern Range) (915 MHz) | | 5 |
| Air Force (Eastern Range) (SODARS) | | 5 |
| Air Force (Western Range) (915 MHz) | | 5 |
| Air Force (Western Range) (50 MHz) | | 1 |
| Air Force (Western Range SODARS) | | 2 |
| Army | | 9 |
| NASA (50 MHz) | | 1 |
| | Sub-total | 28 |

| TYPE OF OBSERVATION by AGENCY | | No. of 2008 Locations |
|---|---|---|
| **Doppler weather radar (WSR-88D) sites** | | |
| Commerce (NWS) | | 121 |
| Air Force (U.S. & Overseas) | | 26 |
| Army (US and Overseas) | | 2 |
| Transportation (Off CONUS) | | 12 |
| | Sub-total | 161 |
| **Doppler weather radar (Not WSR-88D) sites** | | |
| Air Force (Fixed) | | 9 |
| Army | | 1 |
| Navy (Fixed) | | 9 |
| Marine Corps (Mobile) | | 10 |
| Marine Corps (Fixed) | | 1 |
| | Sub-total | 30 |
| **Airport Terminal Doppler weather radars** | | |
| Transportation (Commissioned) | | 47 |
| Army (not airfield--Test Range/USAREUR) | | 4 |
| | Sub-total | 51 |
| **Conventional radar (non-Doppler) sites** | | |
| Commerce (NWS) | | 2 |
| Commerce (at FAA sites) | | 27 |
| Air Force, Mobile Units | | 23 |
| Army (U.S. and Overseas) | | 3 |
| Transportation (FAA (WSP)) | | 39 |
| | Sub-total | 94 |
| | Total Radars | 672 |
| **Off-site WSR-88D Principle User Processors (PUPs)** | | |
| Air Force (OPUPs only) | | 97 |
| Marine Corps (U.S. & Overseas) | | 9 |
| Army | | 1 |
| Transportation | | 25 |
| NASA (KSC/AMU) | | 1 |
| | Sub-total | 133 |
| **Weather reconnaissance Aircraft** | | |
| Commerce (OMAO) | | 3 |
| Air Force Reserve Command (AFRC) | | 10 |
| | Sub-total | 13 |
| **Geostationary meteorological satellites (No. operating)** | | |
| Commerce (2 primary, 1 standby, 1 servicing South America) | | 4 |
| **Polar meteorological satellites (No. operating)** | | |
| Commerce (2 primary - one US; one European, 3 standby) | | 5 |
| Air Force (2 primary, 3 standby) | | 5 |
| Navy (WINDSAT and GFO) | | 2 |
| | Sub-total | 12 |
| **Electric Field Mills (Surface)** | | |
| NASA (KSC) | | 31 |
| Stennis | | 2 |
| | Sub-total | 33 |
| **Lightning Detection Systems** | | |
| Air Force (Eastern Range) (Cloud - Ground) | | 1 |
| Air Force (Eastern Range) (National Lightning | | 1 |

Section 3

# DEPARTMENT OF AGRICULTURE (USDA) WEATHER PROGRAMS

The Nation's food and fiber products are a critical resource not only to the domestic and international economic situation but also to national security and even foreign policy. Weather is the most important factor influencing the Nation's variability in crop yields and related production. The United States Department of Agriculture (USDA) monitors global weather and agricultural developments through the Joint Agricultural Weather Facility (JAWF). The JAWF provides critical information to decision-makers formulating crop production forecasts, programs that provide natural disaster assistance to U.S. farmers and ranchers, emergency relief programs, and trade policy. USDA operates specialized weather observing networks such as SNOTEL, SCAN, and RAWS that provide vital data and information used to forecast seasonal water supplies in the West, to support national conservation programs, and to monitor the health of the Nation's forests. USDA conducts supporting research that focuses on understanding the interactions of weather and climate with plants, animals, forests, and forest ecological systems.

## METEOROLOGICAL PROGRAMS

Numerous agencies within the USDA require a range of high quality weather and climatological data to carry out their missions. Among these diverse applications, which require accurate, timely, and comprehensive data, are crop monitoring and weather impact assessment, agricultural yield and productivity modeling, natural resource conservation planning, forest fire potential monitoring, irrigation scheduling, water supply information, reinsurance and compliance programs, crop disaster assistance and emergency relief programs, integrated pest management, crop yield modeling, and agricultural research studies. USDA weather- and climate-related activities to support these and other applications are discussed below.

### OFFICE OF THE CHIEF ECONOMIST/WORLD AGRICULTURAL OUTLOOK BOARD

The primary objectives of the World Agricultural Outlook Board (WAOB), which is located within the Office of the Chief Economist (OCE), are consistency, objectivity, and reliability of outlook and situation-related material, including weather information developed within the USDA. It coordinates all weather and climate information and monitoring activities within the USDA. The WAOB also manages the JAWF, which serves as the USDA focal point for weather and climate information and agricultural weather impact assessments around the world.

JAWF, which was created in 1978 as an operational unit, is jointly managed by the USDA/OCE/WAOB and the Climate Prediction Center (CPC) of the National Centers for Environmental Prediction within the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS). The primary mission of the JAWF is to routinely collect global weather data and agricultural information needed to assess the impact of growing-season weather conditions on crops and livestock production prospects. JAWF meteorologists work as a team, monitoring global weather conditions and crop development on a daily basis to prepare real-time agricultural assessments (Figure 3 – USDA

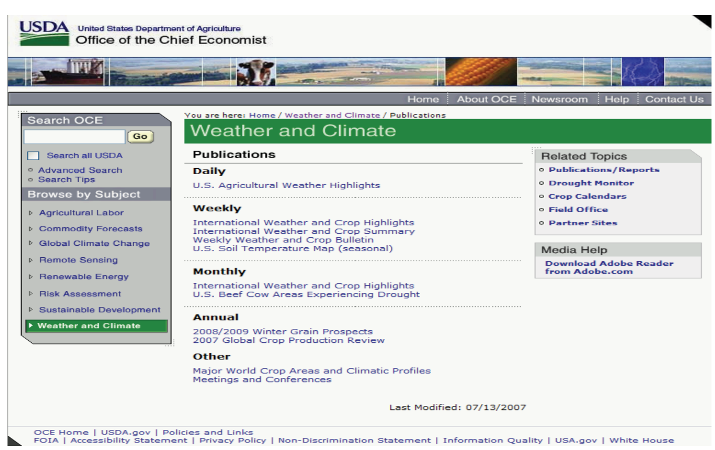



Figure 3-USDA-1. Office of the Chief Economist Web Site

– 1). These assessments keep USDA commodity analysts, the OCE, the Secretary of Agriculture, and other agency leaders informed about worldwide weather-related developments and their effects on crops and livestock.

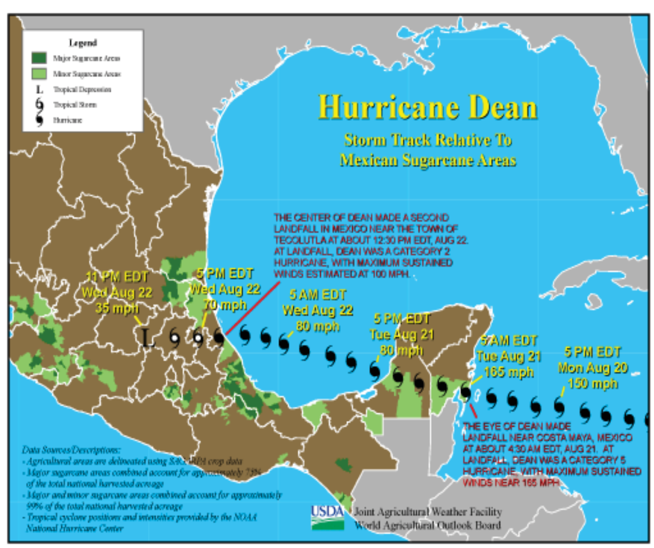
In addition to providing routine assessments, USDA agricultural meteorologists at JAWF are frequently requested to prepare special assessments when adverse or anomalous weather conditions (e.g., droughts, heat waves, freezes, floods, and hurricanes) are observed in major crop-producing regions. Many of these special assessments are prepared using a geographic information system (GIS) to overlay agricultural and weather data; an example of such a product is shown in Figure 3 – USDA – 2. In this example, NOAA National Hurricane Center and Mexican crop data were combined to illustrate the track and intensity of Hurricane Dean relative to Mexican sugarcane areas. When integrated with economic analyses and information, these routine and special crop-weather assessments and analyses provide critical information to decision-makers formulating crop production forecasts, trade policy, and disaster relief. They also help identify potential agricultural markets for U.S. products around the world. Inputs from JAWF are integrated into USDA's monthly foreign crop production estimates. Weekly briefings on global weather and crop development are provided to USDA top staff.

JAWF serves as the USDA focal point for weather data received from the Global Observing System, a worldwide network of nearly 8,000 meteorological reporting stations managed by the World Meteorological Organization (WMO). The WMO data are stored and maintained at JAWF in a sophisticated data warehouse that utilizes advanced database technology to make the data readily accessible to JAWF and other USDA agencies for a number of agricultural applications. JAWF agricultural meteorologists merge these weather data with climatological analyses and global agronomic data to determine the weather's impact on crop development and yield potential. A major source of domestic weather and climate data often used in special operational crop and weather analyses for the United States is the NWS Cooperative Observer Network of over 3,500 daily reporting stations.

JAWF's flagship publication is the Weekly Weather and Crop Bulletin (WWCB), which is jointly produced by WAOB, the USDA National Agricultural Statistics Service (NASS), and the CPC. First published in 1872 as the Weekly Weather Chronicle, this publication has evolved over the past 136 years to become a vital source of information on weather, climate, and agricultural development worldwide. The publication is a shining example of how two major departments (USDA and DOC) within the Federal Government can cooperate, combining meteorology and agriculture to provide a service that benefits the economic well being of the Nation. The WWCB highlights weekly meteorological and agricultural development on a national and international scale, providing written summaries of weather and climate conditions affecting agriculture, as well as detailed maps and tables of agrometeorological information appropriate for the season (Figure 3-USDA-3). The WWCB also provides timely weather and crop information between the monthly Crop Production and World Agricultural Supply and Demand Estimates reports, issued by USDA/NASS and WAOB, respectively. The WWCB is available in electronic form from the OCE web site at http://www.usda.gov/oce/weather/index.htm.

Knowledge of historical climate data and agricultural production patterns in agricultural regions around the world is critical in JAWF's assessments of weather's impact on crop yields. In September 1994, JAWF first published the Major World Crop

Figure 3-USDA-2. Special Agricultural Assessment-Hurricane Dean impacts to Mexican Sugarcane



Areas and Climatic Profiles (Agricultural Handbook No.664). An electronic version of the handbook was developed to provide periodic updates to the printed version as additional data become available. The updates to this seminal reference still provide the frame-work for assessing the weather's impact on world crop production by providing information on climate and crop data for key producing regions and countries. Coverage includes major agricultural regions and crops; among the latter are coarse grains, winter and spring wheat, rice, major oilseeds, sugar, and cotton. World maps show the normal developmental stage of regional crops by month. The electronic version is available from the OCE web site at http://www.usda.gov/oce/weather/pubs/Other/MWCACP/index.htm.

Drought is one of the most costly natural disasters affecting the United States. In the summer of 1999, a monitoring tool known as the U.S. Drought Monitor (USDM) was developed to help assess drought conditions in the United States. Produced weekly, the USDM is a synthesis of multiple indices and impacts depicted on a map and in narrative form. It is a collaborative effort of Federal and academic partners, including the University of Nebraska-Lincoln National Drought Mitigation Center, JAWF, NOAA/NWS/CPC, and NOAA's National Climatic Data Center. Approximately ten lead authors rotate the responsibility of preparing the weekly issue. The National Drought Mitigation Center hosts the USDM on its Web site at http://www.drought.unl.edu/dm/monitor.html. The USDM is released each Thursday at 8:30 a.m. Eastern time. Because the USDM is prepared in a GIS, it can be overlaid on agricultural data to create products that quantify the spatial extent of drought affecting various agricultural commodities (Fig-ure 3-USDA-4). These agricultural weather products, along with the USDM, serve as the main source of information for briefing USDA's Drought Task Force on U.S. drought conditions.


Volume 94, No. 44 http://www.usda.gov/oce/waob/jawf/wwcb.html October 30, 2007

WEEKLY WEATHER AND CROP BULLETIN

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

U.S. DEPARTMENT OF AGRICULTURE
National Agricultural Statistics Service
and World Agricultural Outlook Board

11:25 AM PDT, October 23, 2007
Image courtesy of MODIS Rapid Response Project at NASA/GSFC

Howling winds, high temperatures, and low humidity combined to fan more than a dozen large wildfires across southern California, beginning during the weekend of October 20-21. In the last quarter-century, three California wildfire outbreaks each caused more than $1 billion in losses, according to the National Climatic Data Center. Those outbreaks occurred in 1991 (mainly in Oakland), 1993, and 2003. The latest firestorm, with nearly 2,000 homes and businesses destroyed across southern California, seems likely to join the list.

**HIGHLIGHTS**
October 21 - 27, 2007
*Highlights provided by USDA/WAOB*

Santa Ana winds across **southern California** fanned more than a dozen large wildfires, which consumed at least 515,000 acres of vegetation and nearly 2,800 structures—including about 1,800 homes. Winds subsided by mid-week, allowing wildfire containment and recovery efforts to proceed, but warm, dry conditions persisted. Elsewhere **west of the Rockies**, mild, mostly dry weather promoted fieldwork and **Northwestern** winter wheat emergence and development. Farther east, dry weather finally settled across the **eastern Plains** and **western Corn Belt**, following record-setting rainfall

*(Continued on page 5)*

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Figure 3-USDA-3. Weekly Weather and Crop Bulletin.

The North American Drought Monitor (NADM) is a cooperative effort of drought experts in Canada, Mexico, and the United States to monitor drought across the continent. It was initiated at a workshop in April 2002 and is part of a larger effort to improve monitoring of North American climate extremes. Issued monthly since March 2003, the NADM is based on the end-of-month USDM analysis and input from scientists in Canada and Mexico. Major participants in the NADM program include the entities involved with the production of the USDM, Agriculture and Agrifood Canada, the Meteorological Service of Canada, and the National Meteorological Service of Mexico. The NADM Web site is: http://www.ncdc.noaa.gov/oa/climate/monitoring/drought/nadm/index.html.

The National Integrated Drought Information System (NIDIS) Act of 2006 (Public Law 109-430) was signed by the President in 2006. One of the goals of NIDIS, which is led by NOAA, is to build upon existing drought monitoring tools and experiences, such as the USDM, to develop an early warning system that aids in preparing for and mitigating the effects of drought. The recommendations for such an early warning system were outlined in a 2004 report from

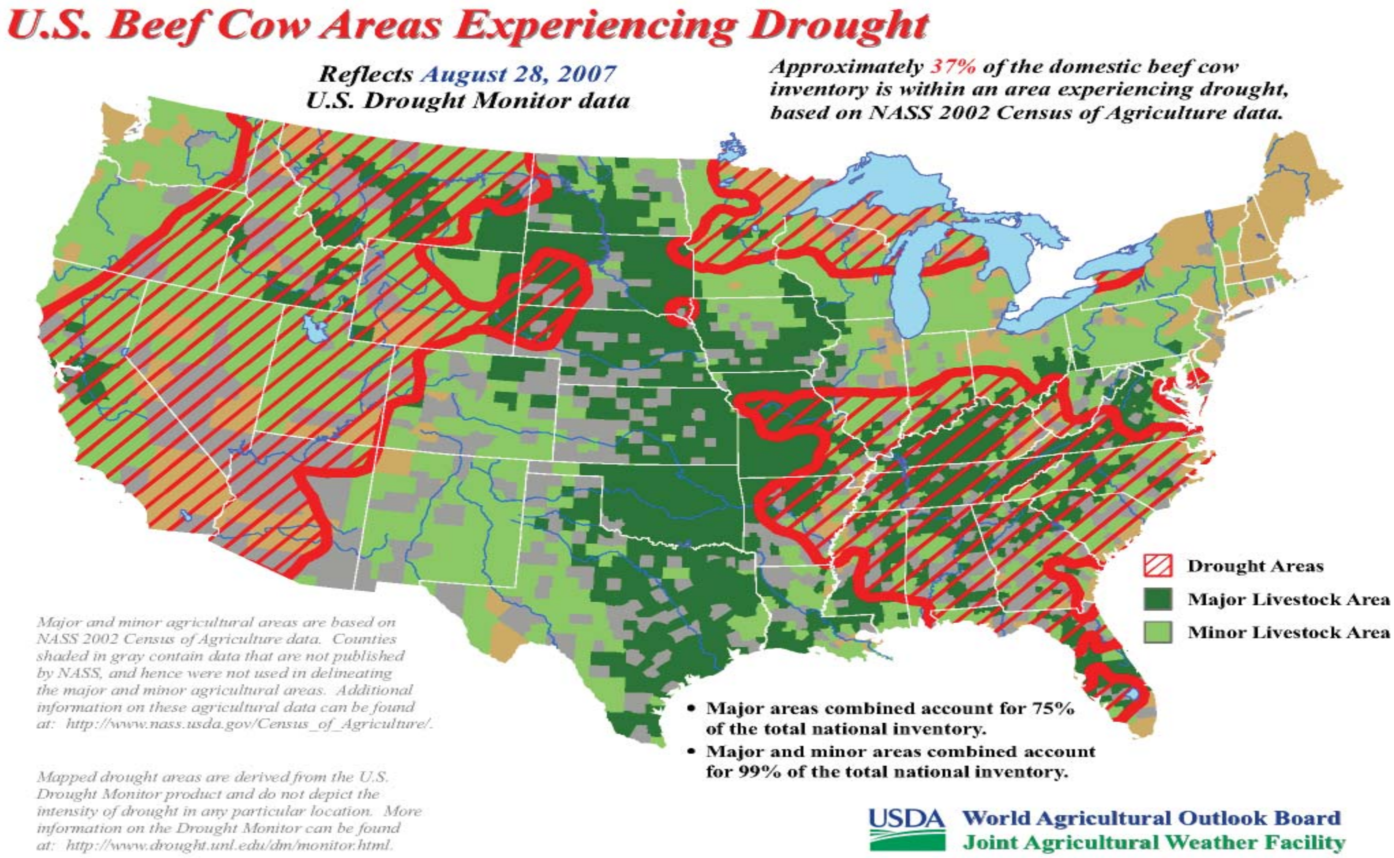



Figure 3-USDA-4. Monthly Update of US Beef Cow Areas Experiencing Drought

the Western Governors' Association (WGA) entitled Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System. A NIDIS program implementation team drawn from Federal and state agencies, academia, and the private sector developed the NIDIS implementation plan, which was released in June 2007. This document describes the NIDIS implementation strategy and governance structure. OCE is one of several USDA agencies with a lead role in developing NIDIS, working closely with NOAA and the WGA over the years to address the specific needs of the agricultural community. One of the early NIDIS deliverables is the Drought Portal (http://www.drought.gov), which serves as the Government's multi-agency drought interface.

USDA's Chief Meteorologist is currently serving on the Management Group of the World Meteorological Organization's (WMO) Commission for Agricultural Meteorology (CAgM). He continues to lead an effort to enhance the flow of more accurate and timely global agricultural weather information through an ongoing project, the World AgroMeteorological Information Service (WAMIS). WAMIS is a dedicated Internet web server (http://www.wamis.org) that hosts agrometeorological bulletins and advisories issued by WMO members for the global agricultural community. It also provides training modules to aid WMO members in improving their agrometeorological products. Currently, 32 member services contribute advisories and bulletins to the WAMIS web server. The Chief Meteorologist also serves as CAgM's focal point to WMO's Natural Disaster Prevention and Mitigation Program.

In October 1998, the JAWF opened a field office in Stoneville, Mississippi, co-located with the Mississippi State Delta Research and Extension Center (DREC) and USDA's Agricultural Research Service (ARS) Mid-South Area Jamie Whitten Delta States Research Center. This OCE/JAWF field office was established to build an agricultural weather network aimed at linking agricultural weather data collection networks already in existence but not part of the current NOAA/NWS basic reporting network. In partnership with USDA's Natural Resources Conservation Service (NRCS), Soil Climate Analysis

Network (SCAN) sites were installed in the Mississippi Delta to enhance the regional network.

## FOREST SERVICE

### Research

Air pollution effects (primarily nitrogen deposition and ozone) remain a serious threat to forest health in some parts of the United States. Forest Service Research (FSR) is documenting long-term effects of air pollution on forests of the Sierra Nevada, Colorado, the Northeast, and southwestern Wyoming. Atmospheric deposition of nitrogen and sulfur has been studied for many years in eastern forest watersheds, and a recent study has demonstrated that increased nitrogen deposition can affect water quality and ecosystem function in western forests as well. In cooperation with the European Union (EU) International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests and National Forest Systems, FSR has been developing a comprehensive approach to critical loads in selected forest ecosystems across the United States, to learn more about potential nationwide impacts. FSR is also working closely with universities to develop measures for critical levels of ozone on public lands. During 2006, FSR Southern Research Station developed the first critical loads map for the entire United States, an important product that will be published after peer review is complete. During 2007, $459K was invested in equipment to establish Level II plots on 20 Forest Service Experimental Forest Range and Watershed sites for monitoring critical load in accordance with the protocol established by the EU international cooperative program.

Smoke from forest fires and other biomass burning is a growing issue as use of prescribed fire in ecosystem management increases. Among the concerns are exposure of fire fighters and citizens to forest fire smoke, changes in visibility and haze, and smoke contributions to regional and local air pollution. FSR is the world leader in developing emissions factors from fires and modeling emissions dispersion. It has conducted research on impacts of smoke on human health, relationships between on-site meteorology and smoke dispersion, consequences of smoke to visibility in Clean Air Act Class I Areas, and the potential of smoke to exacerbate ozone episodes. FSR has provided basic research to support states' air regulatory programs and the U.S. Environmental Protection Agency's (EPA) development of air quality standards. Through five consortia for advanced atmospheric modeling, real-time smoke and fire weather research products are supplied to fire and air quality managers continuously. These products include forward predictions of impacts out to 72 hours in the future.

### Forest Service Weather Program

The Forest Service weather program works with the USDA Drought Commission. It provides key liaison with the Satellite Telemetry Interagency Working Group (STIWG) on satellite services and with the NWS, U.S. Department of Interior (USDI), and National Wildfire Coordinating Group (NWCG) on the delivery of fire weather forecasting. These activities are critical to the safety and effectiveness of wildland fire fighting, for flash flood warnings, and for water supply forecasts. The weather program oversees the standards for approximately 850 remote automated weather stations (RAWS) across the country. The RAWS network provides the observational basis for assessing local fire danger, prepositioning fire fighting resources, and conducting prescribed fire operations to mitigate wildfire risk and preserve ecosystem health. Program costs include contracts for the delivery of this information to the agency personnel, fire weather forecasters, and state forestry agencies that use the data in real-time for critical decisions.

### Wildland Fire Management

This program uses meteorological data and interpretation skills to support wildland fire management. The Forest Service State and Private Forestry, Fire and Aviation Management program operates a network of approximately 850 RAWS, of the total 2200 RAWS nationwide. The RAWS network provides real-time information to the Weather Information Management System (WIMS), which is used by wildland fire management agencies across the country.

The wildland fire program works closely with the STIWG and its associated Technical Working Group; NWS; USDI agencies including the Bureau of Land Management, Fish and Wildlife Service

(FWS), Bureau of Indian Affairs, and National Park Service; State fire protection agencies; and NWCG on the delivery of fire weather data and forecasting. It oversees the standards for the nationwide RAWS network and manages the Interagency RAWS Website (http://www.fs.fed.us/raws). The costs include maintenance support contracts, maintenance training sessions, and contracts for delivery of information to the Federal and state agency personnel, fire weather forecasters, and foresters who need timely data for critical decisions.

The Forest Service weather program works with the National Predictive Services Group at the National Interagency Fire Center (NIFC) in Boise, Idaho, to provide technical support and oversight to 10 Geographic Coordination Centers. It also works closely with Forest Service R&D staff in overseeing the five Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) locations. The FCAMMS effort, in cooperation with NOAA and EPA, provides valuable fire weather, smoke forecasting, and air quality information to fire and air quality programs. The FCAMMS and Predictive Services Group provide critical information for planning wildland fire activities and for operational decision-making during fire events.

## NATURAL RESOURCES CONSERVATION SERVICE (NRCS)

### Snow Survey and Water Supply Forecasting-Monitoring

Snowmelt provides approximately 80 percent of the stream flow in the West. The NRCS, in partnership with other Federal and state agencies, operates the Snow Survey and Water Supply Forecasting Program (SS&WSF) in 12 Western states and Alaska. To accurately forecast seasonal water supplies, the SS&WSF collects critical snow and climate data from high elevation snowpacks in the mountainous West. The data collection system includes 1,200 manual snow courses and 750 automated SNOTEL (SNOwpack TELemetry) monitoring stations throughout the Western States and Alaska. These data, along with information from 756 stream gages, 328 major reservoirs, and 3,200 climatological observation stations are merged into a hydroclimatic database that is used to produce real-time watershed analyses and water supply forecasts. Monitoring is conducted in partnership with Federal, state, and local agencies, power companies, irrigation districts, and the Provincial Government of British Columbia. This information is the basis for water management decisions under international treaties with Canada and Mexico.

The SNOTEL network plays an important role by providing near real-time remote hydrometeorological data required to evaluate snowpacks, potential in-stream water supplies, and drought risk. The SNOTEL network can provide hourly precipitation, temperature, and snowpack depletion information that significantly improves flood stage forecasts and the monitoring of other life-threatening snow-related events. Approximately 25 percent of the SNOTEL sites collect soil moisture and soil temperature measurements. These measurements enable the NRCS and partners to make more accurate stream flow forecasts and mitigate flood and drought impacts. All SNOTEL data are transmitted hourly to the NWS to assist in forecasting flood events. SNOTEL information enables emergency management agencies to effectively mitigate drought and flood risks. An added benefit during the late spring and summer is the availability of hourly climate data, which are used to monitor and assess forest health and wildfire potential.

Additionally, the SS&WSF supports research to improve monitoring technology, data reliability, data quality, water supply forecasting, and water resource modeling.

### Water Supply Forecasts

Monthly water supply forecasts are produced from January through June in partnership with the NWS. These forecasts: (1) help irrigators make the most effective use of limited water supplies for agricultural production needs; (2) assist the Federal government in administering international water treaties with Canada and Mexico; (3) assist state governments in managing intrastate streams and interstate water compacts; (4) assist municipalities in planning the early management of anticipated water supplies and drought mitigation; (5) support operational decisions on reservoir release, to satisfy multiple use demands including hydropower generation; (6) aid in mitigating flood damages in levied areas and downstream from reservoirs; and (7) support fish and wildlife management activities associated with species protection legislation.

During a typical forecast season, the SS&WSF issues over 11,000 seasonal water supply forecasts for 750 locations in 12 western states. The water supply forecasts are coordinated and peer-reviewed by a number of Federal agencies and cooperators to ensure the highest quality and accuracy. Major cooperators include the NWS, Bureau of Reclamation, U.S. Army Corps of Engineers, Bonneville Power Authority, state and local agencies, power utilities, irrigation districts, Tribal Nations, the Provincial Government of British Columbia, the Yukon Territory, and Mexico. The primary users of this information include agricultural, municipal, industrial, hydropower, and recreation managers. Federal legislation related to endangered species protection has placed increased emphasis on timely and accurate forecasts.

The National Water and Climate Center (NWCC) web site (http://www.wcc.nrcs.usda.gov) provides snow data, analyses, GIS maps, and forecasts to approximately 80,000 users. The web site logged over 22 million user accesses to data reports and products during the water year 2007.The NWCC recently implemented a Daily Water Supply Guidance Forecast product for 138 western basins, available at http://www.wcc.nrcs.usda.gov/wsf/daily_forecasts.html. The procedure for this product uses SNOTEL snowpack and precipitation data to calibrate and generate an updated water supply volume forecast every day. It provides water managers with intra-month water supply forecast trend analysis between the coordinated monthly water supply forecasts.

<u>Drought Assessment</u>

The SS&WSF provides a variety of climate and water supply products that are used to assess drought conditions in the Western States. These products include SNOTEL snowpack and precipitation analyses for the mountains, water supply forecasts, and State Surface Water Supply Indexes (SWSI). These products are critical to the production of the weekly interagency Drought Monitor, a web-based report. A cooperative, nationwide network of approximately 150 Soil Climate Analysis Network (SCAN) sites in 39 states monitors soil temperatures and soil moisture to support national drought monitoring, production agriculture, and climate change research.

<u>Climate Information</u>

NRCS provides climate data and products that directly support agriculture and conservation activities nationwide through the NWCC webpage and the Agricultural Applied Climate Information System (AgACIS), which is accessible through the NRCS Electronic Field Office Technical Guide webpage. The AgACIS is an Internet-based climate data delivery system developed in partnership with the six NOAA Regional Climate Centers. It provides the NRCS field offices, other USDA agencies and offices, and other partners with Internet access to thousands of climate datasets collected by scores of Federal, state, and county networks. Digital maps of monthly and annual precipitation and temperature for the United States are available from the NWCC webpage. NRCS's long-range planning is supported by the Generation of Weather Elements for Multiple Applications Model (GEM), which has been used to generate future climate data sets for more than 250 locations nationwide. GEM is being integrated with several NRCS environmental models, as well as being used for the NRCS Conservation Effects Assessment Program. Also available from the NWCC webpage are monthly precipitation averages and growing season length information, which is required for wetlands analysis, for more than 6,000 locations in the United States, Guam, and Puerto Rico. Wind roses, which are useful for agricultural and natural resource planning, are available on the NWCC webpage for 237 NWS stations in the United States, Guam, and Puerto Rico. A wind rose gives a succinct but informative view of how wind speed and direction are typically distributed at a particular location.

## AGRICULTURAL RESEARCH SERVICE

Variable weather patterns associated with global climate change are affecting natural resource systems needed for agricultural production and watershed ecosystem services. The increasing importance of these effects is creating a need for new knowledge, which in turn requires weather and climate-related observation, prediction, and adaptation technologies. ARS weather and climate research activities focus on how short- and long-term weather patterns affect crop and animal production; hydrologic processes; the availability of water from watersheds; the environmental and economic sustainability of food, feed, fiber and bioenergy production; and ecosystem services such as clean air and water. The research is conducted to provide risk management tools and reliable decision-making criteria to producers, land managers, and policy-makers. ARS scientists are developing algorithms and decision support systems with the NRCS, NASA, and NOAA to improve prediction of snowpack distribution and timing of snowmelt and water availability in the Western United States. The ARS experimental watershed program actively participates in the NWS effort to modernize the Cooperative Observer Network so that the information needs of agriculture are addressed by this national surface observation network. ARS works with scientists at NOAA, NASA, JAWF, and in the academic community to improve observation, prediction, and impact assessments of drought across the United States. ARS is leading development of new technology to mitigate the impact of drought via more efficient water management strategies and the use of non-potable water (gray water) to augment irrigation water supplies during times of drought.

Another research goal is to identify and collect the information needed to develop best-management practices for reduction of soil loss and sedimentation and to predict flooding occurrence. Synthesis and integration of seasonal weather forecasts, information on extended climate departures from normal, the occurrence of extreme weather events, and agroecosystems response to weather and climate variations are being integrated into planning and management tools readily usable by agricultural producers. This research is also conducted in collaboration with NOAA, NASA, and academic scientists. ARS is developing a combined wind and water erosion model for nationwide conservation management practice planning. This model incorporates a wind erosion model recently transferred to NRCS.

ARS scientists conduct research to understand the processes of air pollution emissions from agricultural systems and the effects of air quality upon agriculture. ARS scientists are working with agricultural producers, industry, EPA, NASA, NOAA, NRCS, the Forest Service, and academic scientists to develop and test control measures to reduce gas emissions, including greenhouse gases, from a variety of agricultural enterprises.

## COOPERATIVE STATE RESEARCH, EDUCATION AND EXTENSION SERVICE

Funding for the Cooperative State Research, Education and Extension Service (CSREES) supports research projects that collect, process, and utilize long-term weather and climate data to provide a base of information for the projection and prediction of climatic trends related to environmental impacts of human activities, soils, crops and domestic animals on agro-ecosystems, forests, and rangelands. Broader areas of study involve climate dynamics, carbon and water cycling, and the role these factors play in global change. Studies on the impact of changes in UV and ozone levels also fit in this category of research.

Historical climate changes are related to trends visible from present data-gathering studies, enabling prediction of future crop production and irrigation needs. CSREES supports studies on the impact of climate and weather on food and fiber production and on natural resource protection. These studies relate to forest plant growth, rangeland productivity, cropping system selection, livestock production practices, and natural resource management. Human impact on climate systems is also well represented in studies of both micro- and macro-climatic change. These studies investigate the climatic effects on air quality, water quality, and point/nonpoint pollution related to agricultural practices and forest and urban development. Studies on the effects of climate variation on nutrient cycling and carbon sequestration and emission are supported with CSREES funds. Other supported research quantifies the impact of climate change on the incidence and severity of plant and animal diseases and pests, invasive species, and biodiversity.

The CSREES National Research Initiative (NRI) has funded projects on a variety of weather and climate research in collaboration with other Federal agencies. The current focused research areas of NRI's Global and Climate Change Program are carbon cycling, land use dynamics, and invasive species. Other NRI areas of weather and climate research range from fundamental plant drought-tolerance studies to using meteorological data to forecast market performance. CSREES funding in the FY 2009 President's Budget for weather and climate studies is expected to be reduced from FY 2008, due to proposed decreases in the Hatch Act, McIntire-Stennis, Evans-Allen, and Animal Health formula programs and decreases in Special Research Grants and Federal Administration projects.

# 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 NOAA Marine and Aviation Operations (NMAO).

## NATIONAL WEATHER SERVICE

The United States is prone to a range of severe weather phenomena. Each year, Americans cope with an average of 10,000 thunderstorms, 5,000 floods, and 1,200 tornadoes, as well as land-falling hurricanes. Some 90 percent of all Presidentially-declared disasters are weather related, causing approximately 600 deaths per year and $14 billion in damage. According to the American Meteorological Society, weather is directly linked to public safety, and about one-third of the U.S. economy (about $4 trillion) is weather sensitive.

Sectors of the U.S. economy increasingly recognize the impacts of weather, water, and climate on their businesses, and are becoming more sophisticated at using weather, water, and climate information to make better decisions. To meet this growing demand for information and to improve the timeliness and accuracy of warnings for all weather related hazards, the NWS will continue to enhance observing capabilities, improve data assimilation to effectively use all the relevant data NWS and others collect. NWS will also improve collaboration with the research community, make NWS information available quickly, efficiently, and in a useful form (e.g., the National Digital Forecast Database or NDFD) and include information on forecast uncertainty to help partners and other users make fully informed decisions.

With about 4,700 employees, the NWS provides a national infrastructure to gather and process data worldwide from the land, sea, and air. This infrastructure enables data collection using technologies such as Doppler weather radars, satellites operated by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), data buoys for marine observations, surface observing systems, and instruments for monitoring space weather and air quality. These data feed sophisticated environmental prediction models running on high-speed supercomputers. NWS' highly trained and skilled workforce uses powerful workstations to analyze all of these data to issue climate, public, aviation, marine, fire weather, air quality, space weather, tsunami, river and flood forecasts and warnings around the clock. A high-speed communications hub allows for the efficient exchange of these data and products between NWS components, partners, and other users. NWS forecasts and warnings are rapidly distributed via a diverse dissemination infrastructure including NOAA Weather Radio. Finally, outreach, education, and feedback are critical elements to effective public response and improvements to NWS services.

The National Weather Service (NWS) provides climate, water, and weather 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, Great Lakes, coastal, and ocean conditions.
- Observes and reports the weather and the river and ocean conditions of the United States and its territories.
- Develops and operates national meteorological, hydrological, climate, space weather, and oceanic service systems.

- Performs applied meteorological, hydrological, oceanic, space environmental and climate research.
- Assists in developing community awareness and educational materials and programs concerning weather-related natural disasters.
- Participates in multilateral forums to promote international hydrometeorological and space weather policy. This includes activities that facilitate the exchange, coding, and monitoring of data and forecasts. Operational activities such as the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program serve to improve the products and services of NWS.

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

- Organic Act of 1890 created the U.S. Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the U.S. Weather Bureau to enter into cooperative agreements for providing agriculture weather services.
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.
- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for providing 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).
- International Convention for the Safety of Life at Sea (SOLAS) agreement to which the United States is signatory. This sets international policy for safer shipping and cleaner seas. The United States implements the convention through Executive Order 12234 of September 3, 1980 -- Enforcement of the Convention for the Safety of Life at Sea. Among the obligations of the agreement is to provide meteorological warnings and forecasts to ships at sea using charts and radio messages.

## SERVICES AND ORGANIZATION

NWS provides climate, water, weather, oceanic, and space weather prediction services, including watches, warnings, advisories, and forecasts 24 hours a day, seven days a week. These services are provided through a national network of 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), and the 9 centers of the National Centers for Environmental Prediction (NCEP). These offices collect data, prepare local warnings and forecasts, and disseminate information to the public, both nationally and internationally, through NOAA Weather Radio, satellite-based telecommunication systems, radiofacsimile, the media, and the internet. Forecast and warning services prepared at WFOs are derived in part from prediction guidance prepared by the RFCs and the NCEP centers. These centers are the: Hydrometeorological Prediction Center, Storm Prediction Center, Aviation Weather Center, Environmental Modeling Center, Tropical Prediction Center, Climate Prediction Center, Space Weather Prediction Center, Ocean Prediction Center, and NCEP Central Operations. Continually improving the accuracy, timeliness, and accessibility to prediction services is largely a result of research and development both within the NWS and externally from universities and private corporations.

### PUBLIC WEATHER SERVICES

NWS' Public Weather Service Program provides forecast, warning, and response services to the public, private meteorological firms, broadcast meteorologists, and NWS partners who are responsible for public safety. These partners include Federal, State, and local emergency managers and planners. NWS forecasters issue short-duration watches and warnings for severe weather, such as tornadoes and severe thunderstorms, as well as long-duration watches, warnings, and advisories for hazardous winter weather conditions, high wind events, dense fog, and temperature extremes. NWS forecasters support several health related programs such as Air Quality, Heat Health, and the Ultraviolet Index (UVI). Ground based ozone concentration forecasts and an experimental smoke forecasting tool are now being produced for the continental United States. A nationwide air quality forecast capability including concentrations of ozone, particulate matter, and other pollutants is under development. Heat Health Watch Warning Systems (HHWWS) have been developed for select cities to provide advance notice of excessive heat events that produce the greatest number of weather-related deaths. These guidance systems will be expanded to other cities as resources are made available. Also, in partnership with the Environmental Protection Agency (EPA), a climatologically-based ultraviolet alert is being produced for the entire nation. The Public Weather Service

Program serves as the primary focal point for collaboration with federal transportation agencies on weather issues related to surface transportation; with federal, media, and private entities on the UVI; and with the World Meteorological Organization on the provision of public weather services to the international community. Additionally, in partnership with the Department of Homeland Security, NWS forecasters provide meteorological support for response to terrorist acts and other homeland security concerns, as well as accidental releases/spills of hazardous chemical, biological, or radioactive materials.

Since 2004, the National Weather Service has created, and made readily available, forecasts in digital formats. NWS forecasters use their expertise to maintain an up-to-date digital forecast database of sensible weather elements. This information is stored in the National Digital Forecast Database (NDFD). Output from NDFD is available in the form of web graphics on the Internet, in gridded binary format (GRIB2) available via anonymous file transfer protocol and hypertext transfer protocol, in XML via a Simple Object Access Protocol (SOAP) service, and in Geographic Markup Language (GML) or Keyhole Markup Language (KML) via an experimental Web Feature Service. NDFD data can also be converted to a file format that can be used with Geographical Information Systems (GIS). NDFD includes the following operational forecast elements: Maximum Temperature, Minimum Temperature, 12-Hour Probability of Precipitation, Temperature, Dew Point, Weather, Wind Speed and Direction, Relative Humidity, Apparent Temperature, Significant Wave Height, and Probabilistic Tropical Cyclone Surface Wind Speeds and Wind Gusts. In addition, the forecast elements Quantitative Precipitation Forecast (QPF), Snow Amount, Sky Cover became operational on July 8, 2008. Experimental forecast elements include Convective Outlook Hazard Probabilities, and Climate Outlooks. For more detailed information on NDFD, please see http://www.nws.noaa.gov/ndfd/.

## STORM-BASED WARNINGS

The NWS previously issued and disseminated warnings for tornado, severe thunderstorm, flood and marine hazards using geopolitical boundaries. Realizing the continuing need to improve the specificity and accuracy of warnings for tornadoes, severe thunderstorms, floods and marine hazards, the NWS began implementation of Storm-Based Warnings on October 1, 2007. The primary goal of warning by storm-based polygon is improved warning service to the public by minimizing the alerting of areas not in the path of the storm. Storm-Based warning methodology allows the forecaster the opportunity to be spatially specific, eliminating large areas needlessly warned when compared to warning by county. Using GIS software to calculate the size of warned areas, it was shown that warning by polygon decreased the average area warned by almost 75 percent compared to warning by county. More information on Storm-Based Warnings can be found here: http://www.weather.gov/sbwarnings/.

## AVIATION WEATHER SERVICES

NWS' Aviation Weather Services Program funds a broad range of initiatives designed to improve the delivery of aviation weather information to National Airspace System (NAS) users. These initiatives include the acquisition of aircraft mounted water vapor sensors; development of software, tools, and training programs to enhance forecaster effectiveness; and development of products to improve weather information availability to the aviation community. The Aviation Weather Program also serves as NOAA's focal point in the development of the Next Generation Air Transportation System (NextGen). In order to accommodate the projected tripling of demand for air transportation, Congress established the Joint Planning and Development Office (JPDO) to develop and implement NextGen. The NextGen plan will increase NAS capacity by relying on four-dimensional (4D) aircraft trajectories for air traffic management. It will rely on highly automated systems to route air traffic around areas of hazardous weather. These systems, and related decision support tools, will require a 4D digital database of aviation relevant weather elements that will serve as a single authoritative source of aviation weather data. This 4D Database must be continuously updated, internally consistent, and utilize Network Enabled Operations to provide for common situational awareness. The 4D Database will give NOAA the ability to provide airspace users with the current and forecast weather conditions for any point in space, thereby providing for the safe and efficient movement of air traffic. This capability is required to have an initial operational capability by 2012 in order to support the planned automated air traffic management systems.

In order to operationally support the needs of aviation users today, the NWS WFOs prepare Terminal Aerodrome Forecasts (TAF) four times a day, with amendments as needed, for more than 625 public-use airports in the United States and its territories in the Caribbean and Pacific. These offices also produce about 241 individual route-oriented forecasts three times a day for the 48 contiguous States and over the Pacific Ocean.

NCEP's Aviation Weather Center (AWC), the Alaska Region's Alaska Aviation Weather Unit (AAWU), and WFO Honolulu, Hawaii, prepare area forecasts three or four times daily describing general aviation weather conditions over the lower 48 States, the Gulf of Mexico, Caribbean, Alaska, Hawaii and coastal waters, respectively. These three specialized offices also issue in-flight advisories and warnings of hazardous weather conditions associated with thunderstorms, icing, turbulence, and strong, low level winds. The AWC also prepares forecasts of significant aviation weather over the entire globe four times a day (see Figure 3-DOC-1).

NWS Center Weather Service Units located in each of the 21 FAA Air Route Traffic Control Centers provide direct meteorological support to enroute centers, Terminal Radar Approach Controls, airport towers, and Automated Flight Service Stations. These units are operated by NWS, but funded through an Interagency Agreement with the FAA.

The NWS provides weather warnings, advisories, and forecasts to international aviation as one of the International Civil Aviation Organization's (ICAO) 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 four times a day of globally significant thunderstorms, tropical cyclones, severe squall lines, moderate or severe turbulence and icing, and cumulonimbus clouds associated with the above. The forecast charts also include information on volcanoes, radiological releases, jet streams, and tropopause heights. This information is transmitted by the International Satellite Communications System with coverage in the Americas, Caribbean, At-

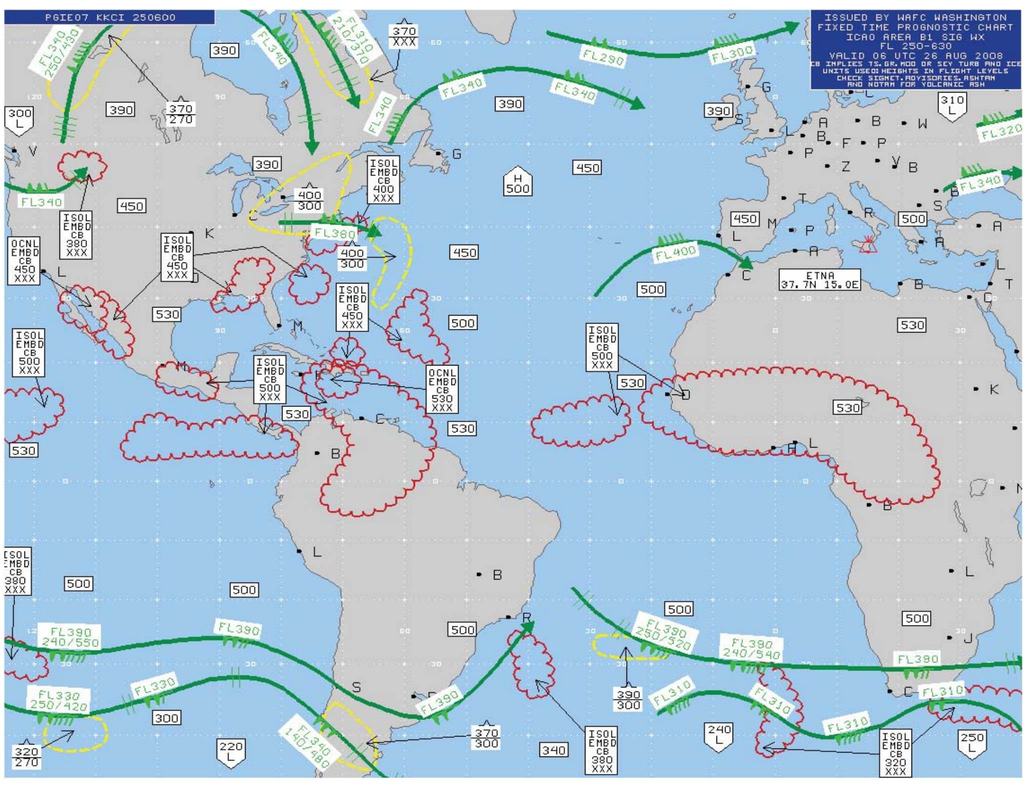


Figure 3-DOC-1 Aviation Weather Center Global Hazard Product

lantic, western portions of Europe, the Pacific, and Eastern Asia.

The United States, in agreement with the ICAO, operates two Volcanic Ash Advisory Centers (VAAC). NESDIS' Satellite Analysis Branch and NWS' NCEP share management responsibility for operating the VAAC in Washington, D.C. Alaska's VAAC is run by NWS' Alaska Aviation Weather Unit. The Washington VAAC area of responsibility includes the continental United States and southward through Central America, the Caribbean to 10 degrees South in South America, and the U.S.-controlled oceanic Flight Information Regions (FIR). The VAAC in Anchorage, Alaska, is responsible for the Alaska and Anchorage FIRs.

## MARINE WEATHER SERVICES

NWS' Marine Weather Program is the lead for the Nation's marine and coastal weather services. Programs include warnings, forecasts, and advisories for coastal waters, offshore, high seas, and near-shore and open waters of the Great Lakes. It leads programs for tropical cyclone, coastal flood, severe convective coastal weather, and coastal hazards such as high surf, rip currents, ice, and tsunamis. NWS forecasters at 46 coastal and Great Lakes WFOs, in collaboration with NCEP's Ocean Prediction Center and Tropical Prediction Center, provide a range of weather services focused on the expanding and weather-sensitive U.S. coastal population.

The Marine Weather Program develops plans, policies, and procedures for the delivery of marine and coastal weather products and services. It ensures marine and coastal forecast training needs are met. The program works with the Office of Science and Technology to prioritize tropical, marine, and coastal science and technology development. The program also works with the Office of Operational Systems for the collection of marine and coastal observations and the delivery of marine and coastal products to users. The program creates internal and external partnerships, collects and validates marine and coastal service and mission needs, solicits feedback on products and services, and validates whether these needs are met.

The program works with NESDIS, the U.S. Navy, and the U.S. Coast Guard (USCG) to provide ice warning and advisory services through the joint National Ice Center. It works with the Navy, the USCG, the U.S. Maritime Administration, and the U.S. Army Corps of Engineers (COE) to safely operate the Nation's Marine Transportation System. It works with the DOD, FEMA, and COE to provide tropical cyclone services; with the USCG, Navy, Air Force, and private entities to disseminate weather to mariners; NOAA's National Ocean Service (NOS) on the PORTS and TIDES programs; and with the World Meteorological Organization to provide services to the international community. It also works in cooperation with NOAA's Office of Response and Restoration, DOD, and Department of Homeland Security for forecasting services for hazardous material spills, marine area search, rescue, and recovery operations, and security needs.

## FIRE AND INCIDENT SUPPORT WEATHER SERVICES

The NWS provides routine pre-suppression and wildfire weather support to Federal and State land management agencies. NWS forecasters provide routine fire weather forecasts, forecast support for the National Fire Danger Rating System, and site specific forecasts during the local fire season over roughly three-quarters of the Nation. The NWS deploys a national cadre of specially-trained Incident Meteorologists (IMET) to provide onsite support for large wildfires and other homeland security concerns, as well as accidental releases/spills of hazardous chemical, biological, or radioactive materials. IMETs use weather instrumentation, telecommunications, and display equipment to aid in onsite forecast preparation and briefings. In the early morning, NCEP's Storm Prediction Center issues outlooks for days 1, 2, and 3-8, that highlight areas with critical and extremely critical fire potential based on the state of the fuels (trees, brush, grasses), and critical weather parameters. Areas where significant lightning activity, accompanied by less than 0.1 inch of precipitation (dry lightning), is forecast are also highlighted. Additionally, NWS forecasters provide forecasts in response to hazardous material incidents or Incidents of National Significance (such as the space shuttle Columbia recovery effort or the Greensburg, Kansas Tornado response).

TSUNAMI WARNINGS

Tsunami warnings, advisories, watches, and information statements for Hawaii and interim watch statements for the Indian Ocean, Caribbean Sea, and South China Sea are prepared by the Richard H. Hagemeyer Pacific Tsunami Warning Center in Ewa Beach, Hawaii. Tsunami warnings, advisories, watches, and information statements for the west and east coasts of the continental United States and Canada, Alaska, the U.S. Virgin Islands, and Puerto Rico are prepared by the West Coast/Alaska Tsunami Warning Center in Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories, sea-level observing stations, and deep-ocean tsunami detection buoys which operate on a cooperative basis. The centers use these data to prepare and disseminate warnings, advisories, watches, and information statements to WFOs, Federal and State disaster agencies, military organizations, private broadcast media, and other agencies involved with warning the public; watch guidance is issued to International users.

CLIMATE SERVICES

Climate prediction products and other services relate to time periods from two weeks to one year in the future, including seasonal forecasts and hazard assessments. NCEP's Climate Prediction Center (CPC) produces a suite of products covering these periods. The climate services program provides the strategic vision for climate services at NWS, oversees the program including the expanded regional and local climate services programs, and serves as steward of the climate observing system. It maintains strong ties with other countries; across NOAA lines, specifically through the NOAA Climate Office; with federal agencies; the university community; and the private sector. The program encourages collaborative arrangements among Regional Climate Centers (managed by NOAA/NESDIS), State Climatologists, and NWS WFOs and regional headquarters to tailor climate forecasts for local users.

HYDROLOGIC SERVICES

The 122 WFOs, 13 River Forecast Centers (RFCs), and NCEP's Hydrometeorological Prediction Center (HPC) and CPC work as a team to provide hydrologic forecast and warning services to minimize loss of life and property from flooding, and to meet the water service needs of our Nation. RFC hydrologists use a modeling system called the NWS River Forecast System (NWSRFS) to forecast river stages at approximately 4,000 locations. HPC provides the quantitative precipitation forecasts, which serve as the primary forecast input for NWSRFS. RFCs also provide long-term water supply forecasts used by water managers in the western United States, where decisions about water allocation and use are particularly critical now, with much of the West still feeling the effects of a long-term drought.

WFOs work collaboratively with the RFCs to monitor hydrologic conditions around the clock. Using RFC guidance, advanced Doppler radar (NEXRAD), and telemetered rain gauge observations, WFOs continuously monitor the threat of flash flooding and urban flooding to provide timely flood watches and warnings to protect life and property.

Partnerships with a variety of Federal, State and local agencies are critical to the NWS' Hydrologic Services Program. For example, the NWS works very closely with the U.S. Geological Survey (USGS), the COE, the Natural Resources Conservation Service (NRCS), the Bureau of Reclamation, the Bureau of Land Management, and FEMA on water related issues including stream gauging, support for flood mitigation activities including flood inundation mapping, river and water supply forecasting, and water management. River stage observations and stage-discharge relationships provided by the USGS are critical to warning and forecast operations for the Nation's rivers. The NRCS furnishes snow measurements that are combined with advanced snow modeling and analysis provided by NOAA's National Operational Hydrologic Remote Sensing Center to support joint NWS-NRCS water supply forecasting in the western United States.

The NWS is implementing the Advanced Hydrologic Prediction Service (AHPS) to provide hydrologic forecasts with lead times ranging from minutes to months. AHPS builds on the existing NWS infrastructure, including AWIPS, NEXRAD, and NWSRFS. AHPS also provides Ensemble Streamflow Prediction, a feature that allows the NWS to quantify forecast uncertainty. This lets decision-makers apply risk-based analyses as they prepare for and respond to flooding, and as they try to balance competing demands on water supply, especially during periods of drought.

Flash floods, typically caused by intense, small-scale convection, are the leading cause of flood fatalities. Another AHPS capability, known as Flash Flood Monitoring and Prediction (FFMP), combines high-resolution radar rainfall observations with GIS technology to provide more accurate and much more precise flash flood forecasts. The added precision provided by FFMP greatly reduces the false alarm rate of flash flood forecasts, making them more credible and leading to better public response, which will ultimately save lives.

AHPS services are provided as a suite of Web-based products (http://www.weather.gov/ahps) that feature user-friendly menus and maps allowing users to zoom in to areas of interest. AHPS also provides opportunities to improve NOAA's analysis and forecast capabilities related to coastal water conditions, through joint efforts with other components of NOAA (e.g., National Ocean Service, Office of Oceanic and Atmospheric Research).

The Water Resources Forecasting Activity is being implemented to build on AHPS and other NOAA services to deliver new services at a higher resolution (down to the neighborhood scale) with more information, such as soil moisture, soil temperature, snow pack, and surface runoff volume. It enables NOAA to provide nationally consistent gridded water quantity and quality condition forecasts via a national digital database which assimilates hydrometeorological data, and a community hydrologic modeling system, which brings the current state of science to NWS hydrology. The national digital database will integrate fresh water resource observations and analysis components such as precipitation estimates, snowpack analysis, and soil moisture data. The goal of this database is to increase the amount, type, and accuracy of water resources information for use within NOAA and by partners and other users.

The Community Hydrologic Prediction System (CHPS) facilitates the sharing of data and models between NOAA, other Government agencies, universities, and private sector research groups to advance water prediction science. CHPS will allow a new suite of high-resolution forecasts (including estimates of uncertainty) to be produced for streamflow, soil moisture, soil temperature, water quality, and many other variables directly related to watershed conditions.

## OBSERVATIONS

Observations form the basis for forecasts and monitoring the environment. The NWS manages programs that produce surface and atmospheric observations in support of a wide range of customers, such as the aviation, climate monitoring, modeling, and research communities. NWS Headquarters establishes policy and standards for all observations and standards and coordinates with other Government agencies and international organizations. The NWS approach for improving observations consists of several efforts:

- Make better use of data from observing systems that currently exist;
- Extend the system life of current observing systems to postpone technical obsolescence;
- Replace obsolete observing systems;
- Implement new observing technologies and communication systems that better meet the data needs of the users of our products; and
- Strengthen the link between user requirements and technology research and development.

## NOAA'S COOPERATIVE WEATHER OBSERVER NETWORK (COOP)

COOP is the Nation's largest and oldest weather network. Modernization of a portion of COOP under the Historical Climatology Network Modernization (HCN-M) is consistent with the President's Climate Change Research Initiative, providing a richer source of data to improve weather, water, and climate forecasting, and to contribute to climate change research. The COOP is the primary source for monitoring U.S. climate variability over weekly to inter-annual time frames. These data are also the primary basis for assessments of century-scale climate change. The modernized network will add to NOAA's vision of an-end-to-end monitoring program.

## NATIONAL DATA BUOY CENTER (NCEP) AND VOLUNTARY OBSERVERING SHIP (VOS) PROGRAM

The NDBC designs, develops, operates, and maintains a network of data-collecting buoys and coastal stations worldwide. The NDBC also implements U.S. participation in the VOS program, which is an international collaboration under the World Weather Watch of the World Meteorological Organization. On any given day, crew members on about a thousand ships participating in the VOS program around the world observe the weather at their location, encode the observations in a standard format, and send the data to World Weather Watch participants via satellite or radio. NWS forecasters use the marine observations from the NDBC data buoy network and the VOS reports to examine conditions for forecast preparation and to verify forecasts after the period of the forecast has passed. Other users rely on these observations and forecasts for commercial and recreational marine activities.

## NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION (NCEP)

NCEP delivers to the Nation and the world, analyses, guidance, forecasts, and warnings for phenomena related to weather, the oceans, climate, terrestrial water, and land surface, as well as space weather. NCEP provides science-based products and services through collaboration with a broad range of partners and users to protect life and property, enhance the Nation's economy, and support the Nation's growing need for environmental information. NCEP is organized into seven science-based, service-oriented centers that generate environmental prediction products, and two central support centers. Each service center depends on the central support centers for observational infrastructure including quality control, data assimilation systems, numerical weather, ocean and climate modeling functions, and communication and product distribution systems in order 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, fire weather, and excessive precipitation with emphasis on the forecast period that ranges from 2-8 hours to the next 6-72 hours. All Tornado and Severe Thunderstorm Watches issued anywhere in the continental United States come from the SPC in collaboration with local NWS Forecast Offices. Also, the SPC prepares Mesoscale Convective Discussions which are technical explanations of developing mesoscale features and their impact on hazardous weather. For longer time periods, the SPC produces the Convective Outlook which is the one, two, or three day forecasts of the probability and intensity of both non-severe and severe thunderstorms (including tornadoes). A product depicting the forecast between days 4-8 for organized severe thunderstorms over the contiguous United States is also available on a daily basis. The SPC also issues one and two day Fire Weather Outlooks for the continental United States, defining areas with critical, extremely critical, and dry thunderstorm fire conditions and potential for defined areas. A 3-8 day Fire Weather Outlook is now operational.

### HYDROMETEOROLOGICAL PREDICTION CENTER

The Hydrometeorological Prediction Center (HPC) provides forecast, guidance, and analysis products and services to support the daily public forecasting activities of the NWS and its customers, and to provide tailored support to other government agencies in emergency and special situations. As part of this mission, HPC prepares Quantitative Precipitation Forecasts (QPF) used by the RFCs to develop local river and flood forecasts and by WFOs to develop local rainfall, snow and ice 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. A Model Diagnostic Discussion product, which discusses model trends, biases and differences, is issued four times per day. Additionally, HPC serves as the backup to the National Hurricane Center. From September 15 through May 15, HPC staffs a Winter Weather Desk for two shifts per day, issuing probability graphics for snow and freezing rain as well as a graphic depicting the position of low pressure systems impacting the continental United States in 12 hour increments out to 72 hours into the future. HPC also operates International Desks with the mission of providing visiting scientists meteorological training with an emphasis on the operational use and application of numerical model products. In December 2007, HPC began issuing daily products for the 4-8 day range from its newly established experimental Alaskan Desk. This Desk is part of NCEP's commitment to providing meteorological support for areas outside of the continental United States.

## AVIATION WEATHER CENTER

The Aviation Weather Center (AWC) issues warnings, forecasts, and analyses of weather hazardous to aviation. These efforts support the FAA's Air Traffic Control (ATC) responsibility to safely and efficiently manage the national airspace. The AWC provides wind and flight hazards (e.g., convection, icing, turbulence) forecasts for flight planning and enroute aircraft operations for the United States, the Gulf of Mexico, the Caribbean Sea, Atlantic and Pacific routes in the Northern Hemisphere, and some routes in the Southern Hemisphere. In addition, every two hours, the AWC issues the Collaborative Convective Forecast Product (CCFP), a graphical representation of expected convective occurrence at 2-, 4-, and 6-hours after issuance time. Its purpose is to aid in the reduction of air traffic delays, reroutes, and cancellations influenced by significant convective events. It is produced March through October through a collaborative process involving AWC forecasters along with aviation forecasters from commercial airlines, Center Weather Service Units, and the Meteorological Service of Canada. The AWC is a major component of the U.S. World Area Forecast Center (WAFC), and is an international Meteorological Watch Office. As such, the AWC incurs a mutual backup responsibility with the other WAFC in Bracknell, England. Each office covers an overlapping two thirds of the globe. The resulting products are furnished as an obligation of international treaties.

## ENVIRONMENTAL MODELING CENTER

The Environmental Modeling Center (EMC) improves NCEP's numerical climate, water, and weather predictions through data assimilation and computer modeling. To provide mesoscale predictions (thunderstorms, hurricanes, tornadoes, blizzards, etc.), ocean predictions, and global weather and climate predictions, EMC develops data assimilation systems, as well as global, regional and mesoscale models of the atmosphere, land surface, and ocean. The EMC uses advanced modeling methods developed internally and cooperatively with universities, the international scientific community, NESDIS, NOAA laboratories, and other government agencies. As an example, EMC is a partner in the NASA/NOAA Joint Center for Satellite Data Assimilation (JCSDA) designed to accelerate the use of research and operational satellite data in NCEP operational models. 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 develop ideas, numerical models, and forecast techniques to implement model improvements and improve NWS products. The EMC conducts applied research and technology transfers and publishes research results in various media for dissemination to the world meteorological, oceanographic, and climate community. EMC also participates in ongoing interactive research programs such as NOAA's Hurricane Forecast Improvement Project (HFIP) and the community Weather Research and Forecast (WRF) model. Furthermore, EMC is participating in the Winter Storm Reconnaissance Program in the Pacific through targeted observations aimed at improving forecasts across the country. In addition, at NCEP, led by the EMC, the ensemble approach has been applied operationally at the short, medium and extended range. EMC efforts with collaborative development have resulted in improvements to mesoscale and global models, as well as advancements in hurricane track forecasts, climate forecasts and air quality forecasts.

## CLIMATE PREDICTION CENTER

The Climate Prediction Center (CPC) provides operational monitoring and prediction of global and regional climate variability, with emphasis on applied research and partnerships, to improve understanding of the global climate system. The CPC develops and maintains data bases for determining current and historical climate anomalies and trends, and provides analyses and assessments of their origins and linkages to the global climate system. CPC products and services cover time scales ranging from the next week (days 6-10) to seasons out to a year in advance. These products cover land, ocean, and the atmosphere extending into the stratosphere. CPC's products include probabilistic 1-month and 3-month outlooks (out to one year) for temperature and precipitation, a U.S. Hazards Assessment, the multi-agency U.S. Drought Monitor, a drought outlook, and El Niño Southern Oscillation (ENSO) discussions and outlooks, among many others. WFOs, as well as the public, private industry, and the national and international research community, use CPC products and climate services. CPC also houses the Climate Test Bed (CTB) to accelerate the transfer of research and development into improved NOAA operational climate forecasts, products, and applications. CTB personnel include scientists from NCEP and other NOAA and non-NOAA organizations.

## SPACE WEATHER PREDICTION CENTER

The Space Weather Prediction Center (SWPC) 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 SWPC 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 SWPC issues to the public, its U.S. Air Force partners, and vendors of value-added services 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. SWPC serves as the international World Warning Agency for the International Space Environment Service (ISES). It exchanges international data (solar wind, X-ray, sunspot, corona, magnetic, and ionospheric measurements) in real-time and issues a consensus set of daily forecasts for international use.

## OCEAN PREDICTION CENTER

The Ocean Prediction Center (OPC) provides atmospheric and oceanographic warning, forecast, and analysis products and services out to five days for the North Atlantic (north of 30 °N) and North Pacific (north of 31 °N) as part of the NWS mission of protecting life and property and enhancing economic opportunity. As part of this responsibility, OPC handles U.S. international meteorological obligations to marine interests under the International Convention for SOLAS. The OPC provides weather and sea state warnings and forecasts for the offshore waters of the United States and the high seas of the Northern Hemisphere north of 30 degrees out to five days for planning and operational purposes. OPC warnings and products go directly to ships and are vital for the protection of life and property at sea, and enhancement of the economy. The OPC also coordinates forecasts with, and provides forecast guidance to, WFOs with coastal responsibilities. The OPC, the Tropical Prediction Center (TPC), HPC, and WFO Honolulu collaborate daily to produce unified and seamless surface weather analyses covering from 30 degrees South to the North Pole, and from East Asia across the Pacific and Atlantic to Western Europe and Africa.

## TROPICAL PREDICTION CENTER/NATIONAL HURRICANE CENTER

The mission of the Tropical Prediction Center (TPC)/National Hurricane Center (NHC) is to save lives, mitigate property loss, and improve economic efficiency by issuing watches, warnings, forecasts, and analyses of hazardous tropical weather, and by increasing understanding of these hazards. The TPC/NHC provides guidance, coordination, and tropical weather expertise to WFO forecasters, the media, and private industry. TPC/NHC services include public and marine advisories, watches, and warnings out to five days for tropical cyclones in the North Atlantic and eastern North Pacific hurricane basins, 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, south of 30 degrees north latitude and a portion of the southeast Pacific. The TPC is also home to the Joint Hurricane Testbed, by which new technology, research results, and observational advances are transferred smoothly and rapidly into improved tropical cyclone analysis and prediction products.

## NCEP CENTRAL OPERATIONS (NCO)

NCO is responsible for 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 maintains and manages the modeling supercomputers and is responsible for running the computer applications that generate all NCEP model 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 leads the technical transition between the research and development of numerical weather and climate prediction models and their operational use on the NCEP computer systems. 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 high performance computer systems, forecaster workstations, personal computers, and a user service that supports all NCEP centers. Since an upgrade to NCEP's main computer systems and facilities in 1999, and throughout subsequent upgrades, NCO has delivered NCEP model forecasts and products to its users with a high degree of reliability and timeliness. NCO also manages two supercomputers; one located in Gaithersburg, Maryland, and the other in Fairmont, West Virginia, as backup. Each day, the operational machine processes up to seven billion meteorological observations (99.9 percent of which are from satellites), and generates more than 14.8 million model fields.

OTHER NWS OFFICES WITH NATIONAL RESPONSIBILITIES

In addition to the NCEP centers, there are three other offices that provide national products. They are the Alaska Aviation Weather Unit, the Anchorage WFO, and the WFO Honolulu/Central Pacific Hurricane Center.

The Alaska Aviation Unit provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for Alaska and surrounding areas. The Anchorage WFO prepares offshore marine forecasts and warnings for interstate and international marine commerce traversing the Gulf of Alaska and the Bering Sea. They also prepare ice analyses and forecasts for the Arctic Ocean, the Bering and Chukchi Seas, and the Cook Inlet. WFO Honolulu/Central Pacific Hurricane Center (CPHC) provides aviation, marine, and tropical cyclone products. In aviation, WFO Honolulu provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for the central North Pacific from 140 degrees West to 160 degrees East longitude, and in the Oakland Flight Information Region south of 30 degrees North latitude through ICAO international agreement. The office handles international meteorological obligations to marine interests under the International Convention for the Safety of Life at Sea (SOLAS). WFO Honolulu provides weather and sea state warnings and forecasts for the high seas of the central North and South Pacific south of 30 degrees North latitude. CPHC issues tropical cyclone advisories, forecasts, watches, and warnings for the central North Pacific including Hawaii.

## 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, water, and climate services to the public.

METEOROLOGICAL 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, water, and climate 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 se-

vere 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.
- Techniques to improve prediction of seasonal to interannual climate variability and their impacts on weather variability.
- Techniques to improve incident data retrieval and display (with NOAA's Environmental Systems Research Laboratory's Global Systems Division).

Hydrologic Research

The NWS develops, implements, and provides operational support for improved hydrologic, hydraulic, and hydrometeorological models. NWS also manages hydrologic data, as well as 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 complementary models in the NWS River Forecasting System.
- Research, development, and implementation of improved ESP procedures which improve forecast accuracy and quantify uncertainty at all time scales.
- 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, improvement of cold region processes in watershed models, and assimilation of data to improve model initialization. Highly specialized hydraulic models for routing river flows will also provide information for generating maps of inundated areas.
- Development of improved multi-sensor precipitation estimates for input into operational hydrologic and atmospheric models. Radar, rain gauge, and satellite rainfall estimates are merged to produce optimum rainfall analyses.
- Development of verification methods to assess the added value of new science and technology to the product user.
- Development of the Community Hydrologic Prediction System (CHPS) to facilitate the sharing of data and models, and allow for production of a new suite of high-resolution forecasts.

Space Weather Research

Research and development at SWPC 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). This applied research is focused on areas where advanced applications can be devised and prototyped to improve the specification and forecast of conditions in the space environment by developing and implementing models and indices, and by obtaining and processing new observations. Activities include:

- Developing the first dynamic, global ionospheric model to use ensemble Kalman filter techniques to assimilate data every 15 minutes. Disparate data from a wide variety of sources will enable the model output to be useful to radio communicators, as well as Global Positioning System (GPS) and Loran users.
- Developing models to characterize and predict geomagnetic storm intensity, both spatially and temporally.

Support for Collaborative Research with the Academic Community and Other Partners

The Collaborative Science, Technology, and Applied Research (CSTAR) program was established to bring NWS-supported collaborative activities with the academic community into a structured program and to create a cost-effective transition from basic and applied research to operations and services. The CSTAR Program issues requests for proposals through which colleges and universities compete for 1-3 years of research funding. CSTAR supports shorter-term research activities with colleges and universities through the NWS/Cooperative Program for Operational Meteorology, Education, and Training (COMET) Outreach Program.

The NWS also funds specific applied research grants and cooperative agreements directly in support of hydrology and meteorology research needs.

**Training**

NWS provides training to its workforce to enhance the professional and scientific development of its staff in support of its mission and strategic goals. Training deficiencies and requirements are identified and addressed via the National Strategic Training and Education Plan (NSTEP) process, described in NWS Instruction 20-102 and available at http://www.nws.noaa.gov/directives/020/pd02001002a.pdf

Training is provided through residence classes and workshops, distance learning methods, Internet modules, teletraining sessions, webcasts, and CD-ROM based training. The NWS Training Center (NWSTC) in Kansas City, Missouri, provides technical, meteorological and hydrologic, and management/leadership training. The Warning Decision Training Branch (WDTB) in Norman, Oklahoma, conducts situational awareness and remote sensing training with modules that integrate data for improving the warning decision process. The Forecast Decision Training Branch (FDTB) in Boulder, Colorado, provides scientific and forecast-decision training. NWS employees also have direct access to scientific and managerial training materials through the Department of Commerce's Learning Center. NWS training is also supported by a partnership with the COMET program located in Boulder, Colorado.

The NWSTC, in addition to providing scientific and technical training, is working to expand its leadership training and development skills through NWS' Leadership Academy. The goal of the Leadership Academy is to enable NWS and NOAA employees to become world-class leaders. The Academy is founded on a sequential and progressive approach designed to develop professional skills and capabilities to improve employee performance. From entry into the agency to senior career status, employees can take advantage of courses and processes that are part of a powerful management and leadership learning environment. Finally, the NWS is working to develop an organized curriculum to supply the necessary knowledge, skills, and abilities for all positions.

**INTRODUCTION**

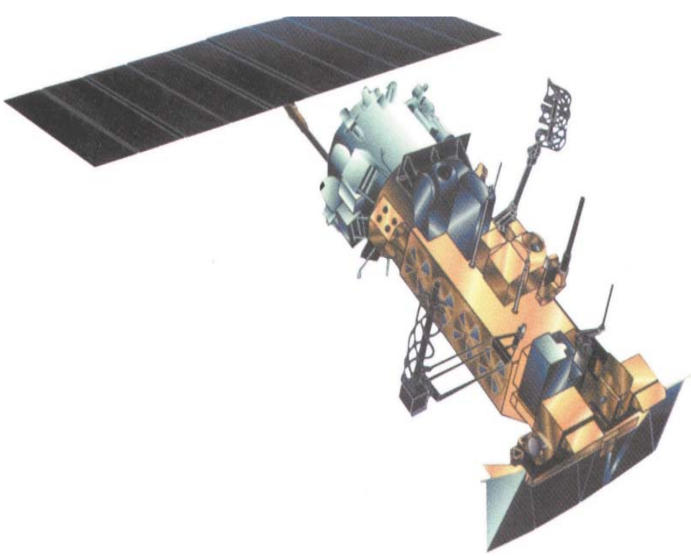
The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS) oversees the daily operations of U.S. civil operational environmental satellite systems as well as NOAA's data centers, which develop global, national, and regional da-tabases to support meteorology, oceanography, geophysics, and the space environment.

NESDIS procures, launches, and operates two types of satellites to provide worldwide environmental data and information products and services to Federal agencies, state and local governments, and private us-ers. These satellite types are the Polar-orbiting Operational Environmental Satellites (POES) and Geostationary Operational Environmental Satellites (GOES).

POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITES (POES)

Polar-orbiting satellites circle the Earth in an almost north-south orbit, passing close to both poles. These satellites ensure that data for any region of the Earth are no more than six hours old. Data from POES support global weather forecasting models, long-term global climate change research, and hazard detection and mitigation. NESDIS operates six polar orbiters. The NOAA-12, NOAA-14, NOAA-15, and NOAA-16 satellites continue to transmit data as stand-by satellites. MetOp-A, a European environmental satellite with three instruments provided by NOAA, is the primary morning satellite; NOAA-17 serves as the backup morning satellite; and NOAA-18 is the primary afternoon satellite. NESDIS also manages the command, control, and communications functions of the Department of Defense's (DoD's) Defense Mete-orological Satellite Program (DMSP).

Figure 3-DOC-2. Polar-orbiting Operational Environmental Satellite



NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

NPOESS, the next generation of polar-orbiting satellites, will provide standard meteorological, oceanographic, environmental, and climatic information as well as space environmental remote sensing information. In addition, NPOESS will continue to provide surface data collection and search and rescue capability. The first NPOESS satellite will begin to collect and disseminate data on Earth's weather, at-mosphere, oceans, land, and near-space environment in 2013. The NPOESS Integrated Program Office (IPO), in consultation with the Polar-orbiting Operational Environmental Satellite (POES) and Defense Meteorological Satellite Program (DMSP) program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued uninterrupted data services. The NPOESS program is managed by the Tri-Agency IPO, employing per-sonnel from the Department of Commerce (DOC), the National Aeronautics and Space Administration (NASA), and DoD. During Fiscal Year (FY) 2009, activities will include, but will not be limited to, assembly, integration, and testing of sensors on the NPOESS Preparatory Project (NPP) satellite; preparation for NPP launch in 2010; pre-launch calibration and validation for NPP; development and testing of sensor flight units for NPOESS; Critical Design Review for NPOESS; expansion of the Antarctic Data Relay site; completion of the Interface Data Processing Segment (IDPS) software builds; Mission Operational Readiness Review for NPP; and NPP Ground Readiness Review. Also in FY 2009, NOAA will work to support remanifesting the Clouds and Earth's Radiant Energy System

(CERES) instrument and the Total Solar Irradiance Sensor (TSIS) and to develop infrastructure for data records archive, access, and assessment. These efforts support the Administration's commitment to restoring high priority climate sensors that were de-manifested from NPOESS in 2006. NOAA is also working with the Office of Science and Technology Policy (OSTP) and the Office of the Federal Coordinator for Meteorology (OFCM) on development and assessment of mitigation options to address the loss of space environmental sensing capability being de-manifested from the planned NPOESS spacecraft and potential loss of the Advanced Composition Explorer (ACE) spacecraft solar wind data.

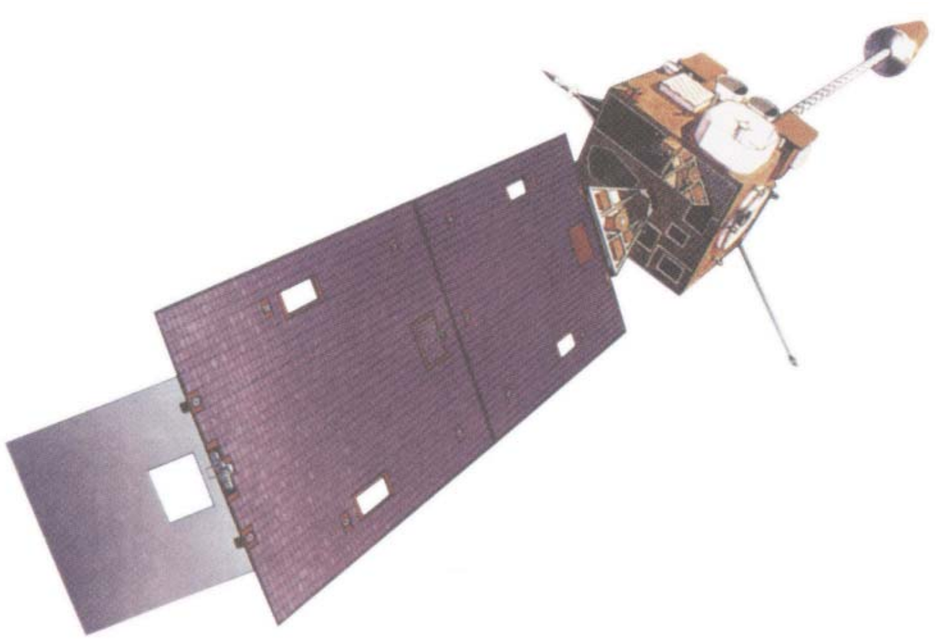
## GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES (GOES)

The GOES spacecraft, in contrast to the POES spacecraft, circle the Earth in a geosynchronous orbit. This means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. These satellites provide continuous monitoring necessary for effective, detailed, and extensive near-term severe weather monitoring and forecasting and long-term environmental monitoring. Each operational satellite continuously views nearly one third of the Earth's surface. GOES-East at 75°W and GOES-West at 135°W provide data on the United States and the Western Hemisphere. GOES-East monitors North and South America and most of the Atlantic Ocean. GOES-West monitors North America and the Pacific Ocean basin. GOES-13 is the on-orbit spare at 105°W and is available for operational deployment when needed. GOES-10 was retired from active service for the United States in December 2006. This satellite is at 60°W and is providing enhanced monitoring for South America through the Global Earth Observation System of Systems (GEOSS) in the Americas initiative. In FY 2009, the next spacecraft in the current GOES series will be launched. GOES-O is slated to launch in April 2009 and will become an on-orbit spare (GOES-14) to support the current GOES mission.

## GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE SERIES R (GOES-R)

Geostationary satellites remain the weather sentinels for NOAA–tracking hurricanes, severe storms, clouds, land, and ocean features. The next-generation geostationary satellite series, called GOES-R, will scan the Earth nearly five times faster than the current GOES, providing users such as meteorologists and government agencies around the world with about 60 times the amount of data currently provided. GOES-R is a collaborative development and acquisition effort between NOAA and NASA; their partnering takes advantage of each agency's expertise. In FY 2009, the GOES-R Program plans to award major contracts for the GOES-R Spacecraft and Ground Systems.

Figure 3-DOC-3 Geostationary Operational Environmental Satellite



## CENTER FOR SATELLITE APPLICATIONS AND RESEARCH (STAR)

The Center for Satellite Applications and Research's (STAR's) mission is to transfer satellite observations of the land, atmosphere, ocean, and climate from scientific research and development into routine opera-tions and to offer state-of-the-art data, products, and services to decision-makers. STAR participates in the life cycle of all operational NOAA satellites–from defining the initial requirements for a satellite mission, through calibration and application of the data after the satellite is in orbit, to archiving and developing products from the data. STAR also works with data from non-NOAA satellites as well for research, to transfer capabilities to NOAA, and to obtain even more observations of the Earth.

STAR investigates how to develop satellite datasets that can be used to assess conditions on the Earth in a timely manner, predict changes, and study long-term trends in the environment. STAR works to create products that monitor atmospheric, oceanic, and environmental hazards; enhance NOAA's infrastructure for remote sensing; reduce the risk of launching new, untested, and very expensive satellites and sensors; and expand its support to users.

### NATIONAL CLIMATIC DATA CENTER (NCDC)

The National Climatic Data Center (NCDC) serves as a national resource for climate information. This data center develops national and global datasets that are used by both government and the private sec-tor. NCDC's mission is to describe the climate of the United States. This data center also acts as the Nation's scorekeeper regarding the trends and anomalies of weather and climate. In addition to archiving a variety of in situ and airborne measurements, NCDC provides archive and access to historical satellite data from GOES and POES. NCDC's climate data are used in a variety of disciplines, including agriculture, air quality, construction, education, energy, engineering, forestry, health, insurance, landscape design, livestock management, manufacturing, recreation and tourism, retail, transportation, and water re-sources management. NCDC's data and products fulfill needs ranging from building code compliance to power plant and space shuttle design.

### NATIONAL GEOPHYSICAL DATA CENTER (NGDC)

The National Geophysical Data Center (NGDC) provides stewardship, products, and services for geophysical data describing the solid earth, marine, and solar-terrestrial environments, as well as Earth observations from space. NGDC's data holdings contain more than 400 digital and analog databases, some of which are very large. As technology advances, so does the search for more efficient ways of pre-serving these data. NGDC also maintains the archive for the Defense Meteorological Satellite Program (DMSP) program, where NOAA provides satellite commanding and data processing support to the Air Force DMSP program. NGDC welcomes cooperative projects with other government agencies, nonprofit organizations, and universities and encourages data exchange. NGDC datasets are used by scientific researchers, the engineering community, disaster management planners, and the public for a wide variety of applications. This data center continually develops data management programs that reflect the changing world of geophysics. In addition, this center works closely with contributors of scientific data to prepare documented, reliable datasets and is continually seeking input on user requirements for data and informa-tion products. NGDC's vision is to be the world's leading provider of geophysical and environmental data, information, and products.

### OFFICE OF SATELLITE DATA PROCESSING AND DISTRIBUTION (OSDPD)

OSDPD manages and directs the operation of the central ground facilities, which ingest, process, and distribute environmental satellite data and derived products to domestic and foreign users. OSDPD serves as the primary operating level interface with the civil sector users of data from operating earth sat-ellites. OSDPD manages the Search and Rescue Satellite Aided Tracking (SARSAT) system and is re-sponsible for coordinating and implementing the United States activities in the international satellite aided search and rescue program, COSPAS-SARSAT. OSDPD also evaluates the effectiveness of the opera-tional ground facilities and procedures in terms of the quality and quantity and assesses the timeliness of the products and services provided. It maintains an inventory of operational products and services and prepares assessments, recommendations, and plans for the initiation of new products and services. In addition, OSDPD provides interpretive analyses of global satellite data to support domestic and interna-tional hazard mitigation activities in the fields of tropical storm position and intensity analysis, airborne volcanic ash detection, heavy rain or snowfall estimates, and smoke and fire analysis.

NATIONAL OCEANOGRAPHIC DATA CENTER (NODC)

The National Oceanographic Data Center (NODC) is a national repository and dissemination facil-ity for global oceanographic data. This data center acquires and preserves a historical record of the Earth's changing environment that is used for operational applications and ocean climate research. NODC is an organization made up of the Oceanographic Data Center, National Coastal Data Devel-op-ment Center, World Data Center for Oceanography, and NOAA Central Library. These centers are inte-grated to provide access to the world's most comprehensive sources of marine environmental data and information. NODC provides end-to-end environmental data stewardship by managing the acquisition, processing, quality control, access, and long-term preservation of oceanographic data. The NODC ar-chive holdings include all the observational data acquired in its original form, as well as data records from national research projects and oceanographic products.

NOAA COOPERATIVE REMOTE SENSING SCIENCE AND TECHNOLOGY CENTER (CREST)

CREST is a multi-institutional center, led by the City University of New York (CUNY). Partner insti-tutions include The City College, Lehman College, the CUNY Graduate Center, Bronx Community Col-lege, and the New York College of Technology in collaboration with four partner institutions, which are Hampton University; University of Maryland, Baltimore County; University of Puerto Rico, Mayaguez; and Bowie State University. CREST programs and activities are aligned with the NOAA Strategic Mission of Environmental Assessment, Prediction, and Stewardship. They are organized into five thematic catego-ries: Science, Outreach, Education, Administration, and Awards and Recognition.

Dr. John Bates, from the National Climatic Data Center (NCDC), led the 2008 External Review for CREST and NCDC's education and outreach program. These programs support a number of CREST ac-tivities such as student education, training, and career development in NOAA-related sciences, including the CREST Summer High School Internship program, the NOAA Educational Partnership Program, and a 2007 NESDIS student summer workshop. Additional activities include exploring opportunities to inte-grate new satellite data in education; conducting science and service programs; and using new data inte-gration and visualization tools and technologies like Science-on-a-Sphere for environmental education and outreach.

## SERVICES

OFFICE OF SATELLITE DATA PROCESSING AND DISTRIBUTION (OSDPD)

OSDPD ingests, processes, and distributes many hundreds of satellite products to various users, including NOAA's NWS. OSDPD manages the ground processing system that delivers critical satellite data and products to the NWS' numerical weather prediction (NWP) models. OSDPD also delivers near-real-time images from the Geostationary Operational Environmental Satellite (GOES) spacecraft, as well as images from polar-orbiting satellites, to the NWS Weather Forecast Offices (WFOs) through NOAAPORT and to the National Centers for Environmental Prediction (NCEP) offices located in Camp Springs, Maryland. Satellite data plays a critical role in the forecast process. NWP models use thousands of global observations from satellites to portray an accurate state of the atmosphere, land, and ocean surface for the models to initialize in their forecast cycles. Imagery from satellites is used in the weather forecast and warning process by the National Centers and by local WFOs. Satellite data over the oceans are usually the only source of environmental information over these data void regions.

NATIONAL ICE CENTER (NIC)

The U.S. NIC, sponsored by the U.S. Navy, NOAA, and the U.S. Coast Guard, is tasked with providing the highest quality operational global, regional, and tactical scale sea ice analyses and forecasts tailored to meet the requirements of U.S. national interests. NIC uses data from polar-orbiting satellites to create guidance products and maps.

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. 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.

### JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA)

Effective environmental prediction requires several elements. One of these is accurate, well-distributed observations of the Earth's environment and numerical models that embody the physical and chemical laws governing the behavior of the Earth's land surface, oceans, and atmosphere. Data assimilation is the mortar that binds these elements into successful prediction systems for weather, oceans, climatology, and ecosystems. JCSDA is a partnership between NOAA, the National Aeronautics and Space Administration (NASA), the U.S. Navy, and the U.S. Air Force dedicated to developing and improving our ability to exploit satellite data more effectively in the United States. JCSDA is a collaborative effort that allows the work required to assimilate the billions of satellite observations available daily to be shared by several agencies. This effort would otherwise be duplicated across the agencies. The goals of JCSDA are to:

- Reduce the average time for operational implementation of new satellite technology from two years to one year
- Increase the use of current satellite data in numerical weather prediction models
- Advance the common numerical models and data assimilation infrastructure
- Assess the impacts of data from advanced satellite sensors on weather and climate predictions

### NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM (NIDIS)

Drought events have far reaching impacts on many aspects of our daily lives, from water management to health to energy consumption and conservation. To mitigate these impacts, NOAA, other Federal and state agencies, partners, and countries, developed the plan for NIDIS. NIDIS is a dynamic and accessible drought-risk information system that was created in response to extended drought conditions, especially in the Western United States, over the past decade. In 2007, NOAA unveiled a new, interactive website called the U.S. Drought Portal (USDP) that allows the public and civic managers to monitor U.S. drought conditions; access forecasts; assess the impacts of drought on their communities; and learn about possible mitigation measures. This website is useful to other countries as nations work to coordinate drought preparedness, response, mitigation, and recovery activities. In FY 2008, NOAA began to institute geographic information system mapping capabilities in USDP. For FY 2009, NOAA will work to integrate enhanced geographic information system capabilities in USDP. Additionally, communities will be unveiled in the portal, serving as a location for subject matter experts to share improvements in drought monitoring, forecasting, and mitigation. These communities will also serve as a coordinating and communications mechanism for NIDIS regional pilot projects.

### COMPREHENSIVE LARGE ARRAY-DATA STEWARDSHIP SYSTEM (CLASS)

CLASS stores large volumes of NOAA's complex data and information such as satellite, radar, and other data and derived products. This system helps NOAA more efficiently preserve the volumes and diversity of valuable environmental data and information being acquired by improved observations and enhanced data products. CLASS also supports convenient access to this data to users worldwide. In FY 2009, NOAA will systematically assess environmental datasets for inclusion within CLASS and plan for additional integration of legacy Information Technology (IT) systems supporting archives. In addition, CLASS will be ready to begin providing secure storage of and access to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) satellite data.

### CLIMATE DATABASE MODERNIZATION PROGRAM (CDMP)

Climate data, such as wind speed and direction, precipitation, temperature, and pressure, are critical to many disciplines and enterprises, including economic research, engineering, risk management, energy resource management, and agriculture. Decision-makers in these and other sectors require easy access to these climate data. CDMP conserves and improves access to environmental data by identifying and transcribing these data from historical analog sources (i.e., paper, film, or other non-digital media) to digital formats. Under CDMP, new digital databases of historical environmental data and information are created. As a result of this program, many existing digital datasets have been extended back in time, in many cases by a century or more. Additionally, the conversion of analog data sources to digital databases and datasets ensures that they are preserved efficiently and inexpensively over the long-term. There are more than 52 million images and over nine terabytes of data now available via web-based software to U.S. government employees and their contractors, educational institutions doing environmental research, and other researchers associated with NOAA projects. In addition, during the past few years over four million hourly weather records were keyed and integrated into the National Climatic Data Center's (NCDC's) digital database holdings.

In 2008, CDMP supported over 77 climate and environmental data rescue projects within NOAA. Most of this data and information was underutilized and unavailable for research and, in some cases, in danger of being lost due to poor quality. The majority of these NOAA rescue projects are multiyear tasks; many spill over into FY 2009 due to the complexity and extent of the imaging, keying, and/or data conversion. The first year of a new NOAA task usually involves a pilot or subset of the entire task, allowing CDMP managers to benchmark costs, time, and labor. CDMP also provided technical and programming support to various systems to help modernize software and delivery systems, making the data accessible to NOAA users. Some major NOAA continuing tasks include: upper air and surface international data rescue projects; geolocation of historical maps and charts; shoreline vectorization and geo-referencing; aerial photography image conversion; and imaging and keying marine logbooks and lightship data, tsunami event gauge records, and International Polar Year imaging.

## GLOBAL OBSERVING SYSTEM INFORMATION CENTER (GOSIC)

GOSIC provides access to data, metadata, and information from the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). This system provides efficient access to data and information and unique tools for searching and accessing data, such as matrices and portals. This system allows users to search for specific data, such as data located at NCDC and other global data centers. GOSIC serves the global observing system community and is a great tool for coordinating the various climate observing activities across NCDC and NOAA. GOSIC continues to play an important role in international and regional data access activities. As a formally registered service of the Global Earth Observation System of Systems (GEOSS) data access project, this will expand in 2009. GEOSS is a comprehensive effort to focus on the societal benefits of earth observations. Furthermore, as the World Meteorological Organization (WMO) moves toward a modernized and comprehensive WMO Information Service (WIS), GOSIC will play an important role in FY 2009 in the overall WIS architecture. From a regional perspective, GOSIC continues to play a significant role in aiding various Pacific Island National Meteorological and Hydrological Services in a number of critical data access and communication functions related to meteorological and climatological data in the region. It serves as a capacity building utility by providing Internet-based web services in concert with the Asia Pacific Data Research Center, which is a NOAA/NCDC funded activity at the University of Hawaii.

## U.S. CLIMATE REFERENCE NETWORK (USCRN)

USCRN is a network of climate stations being developed to provide future long-term homogeneous observations of temperature and precipitation that can be coupled with long-term historical observations to identify and monitor climate change. USCRN data are used in climate monitoring activities to place current climate anomalies into historical perspective. Data from the fully deployed network of 114 stations in the conterminous U.S. (planned by the end of FY 2008) quantify the variance in surface air temperature and precipitation on a national scale. The USCRN climate-quality observations avoid many of the time-dependent biases typically experienced with other surface observing networks. USCRN is quickly becoming the Nation's benchmark network by providing a standard to which satellite, weather radar, and other surface system observations can be validated and verified. USCRN enhances the quality of and confidence in other observations; contributes to the rehabilitation of historical datasets; increases in the volume of data used to detect climate trends; and supports climate monitoring, evaluation, and forecasting. In FY 2009, contingent on available funding, USCRN will expand to Alaska with an eventual planned network of 29 stations.

For FY 2009, we plan to add soil moisture, soil temperature, and relative humidity sensors at 60 USCRN sites in support of the National Integrated Drought Information System (NIDIS). Measurements of soil moisture and soil temperature are one of the most critical parameters for understanding the state of drought throughout the country. The density of those few observing networks configured with soil sensors is woefully inadequate for systematic drought monitoring purposes at either the National or Regional Levels. The deficiency in the area of soil moisture and soil temperature observations and monitoring has a critical impact most notably on agribusiness and silviculture as well as forest fire responsiveness.

NOAA OPERATIONAL MODEL ARCHIVE AND DISTRIBUTION SYSTEM (NOMADS)

NOMADS is a collaborative approach, spanning multiple Government agencies and academic institutions, to address the growing need for remote access to high volume global climate model and numerical weather prediction model data. NOMADS is a network of data servers using established and emerging technologies to access and integrate model and other data. NOMADS enables users to share and compare model results. The goals of this system are to improve access to model data and information; improve weather forecasting; develop links between the research and operational modeling communities; foster collaboration between the climate and weather modeling communities; and promote joint product development to study multiple Earth systems.

In FY 2009, NOMADS will have access to increased bandwidth for user access to data, thereby allowing customers' access to download much larger volumes of data and directly supporting multiple research projects. Collaboration with national partners will continue and the incoming model data (into NCDC's archives) will continue to be accessible via NOMADS in near-real-time. There will be increased linkages with the NOAA Virtual Data System (NVDS) and its Geographical Information System (GIS) Services, providing access to model data via GIS interfaces.

CRYOSPHERIC RESEARCH

The National Snow and Ice Data Center (NSIDC), a center within the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder, receives funding from NOAA and other Federal agencies. NSIDC's research covers a broad spectrum of climate-cryosphere interactions using a variety of observing techniques with special emphasis on Arctic sea ice, Antarctic ice shelves, and satellite-borne measurements. NSIDC has a valuable collection of analog archives, including many thousands of glacier photographs that are being scanned and made available online through the NOAA Climate Database Modernization Program. In addition, algorithms to detect snow, frozen ground, and sea ice in passive microwave images from the Defense Meteorological Satellite Program (DMSP) and NASA satellites have been developed at NSIDC. Current work includes "succession planning" or cross-calibration to continue the climate record as the current Special Sensor Microwave Imager (SSM/I) instrument becomes unstable and a new one comes into use. Other work at NSIDC includes developing models of the physical and mechanical properties of snow and ice in glaciers and the freeze-thaw cycles of soils in Polar Regions; the latter is an important component of hydrological modeling. Other areas of special interest and study are the interactions between sea ice, the ocean, and the atmosphere and the discipline of data management for scientific enterprise.

## RESEARCH

ABRUPT CLIMATE CHANGE

During Fiscal Year (FY) 2009, the Paleoclimatology Branch of the National Climatic Data Center (NCDC) will conduct several studies on abrupt climate change. Specifically, this branch will produce new records of the Indian summer monsoon and conduct research modeling rapid changes in sea ice and rapid changes in the meridional overturning circulation in the Atlantic (a potent influence on large-scale weather patterns). The goal of this research is to create a long-term (multi-century) climate trend record, docu-menting natural variability and abrupt climate changes. These changes are not represented in existing models used to predict future climate change. This research will help scientists understand abrupt changes in climate that have occurred in the past and will likely occur in the future. The data produced will enable decision-makers and society to examine past abrupt climate changes and use the lessons learned to prepare to adapt to future changes.

SNOWFALL IMPACT SCALES

NCDC will extend the Northeast Snowfall Impact Scale (NESIS) to all climate regions of the conti-nental United States. NESIS was originally developed for the Northeastern United States to characterize and rank the severity of snow storms based on snowfall amount and the population of the affected area. NESIS uses a five category classification system: Extreme, Crippling, Major, Significant, and Notable. This index differs from other meteorological indices because it uses population information in addition to meteorological measurements, providing an indication of a storm's societal impacts. This research will benefit decision-makers and society because it will provide rapid assessments of the impacts of snow storms on populated areas of the United States. This information is useful to the Federal Emergency Management Agency (FEMA) and those in commodity markets who need to assess the impact of snow events on social and economic centers of the Nation.

This research work, conducted in cooperation with scientists at Rutgers University's Global Cli-mate Lab, will involve: generating map and tabular data related to the selection of candidate storms; populating the Geographical Information Survey (GIS) maps with station data; identifying candidate snow storms; providing quality control; creating event grids; testing an extension of the impact scale from the Northeast to other regions; and developing automated GIS scripts.

GLOBAL TROPICAL CYCLONE DATABASE DEVELOPMENT

NCDC will develop and maintain a global tropical cyclone best track dataset, which includes the intensity and position of tropical cyclones. This work will result in a "one stop shop" for a quality controlled, homogeneous, annually updated dataset. The dataset will benefit decision-makers and society by providing a comprehensive list of tropical cyclones to improve our understanding of hurricane extremes. Knowing where, when, and at what intensity past storms occurred, can help enhance hurricane forecasts. In addition, a global best track dataset may prove useful for tropical cyclone forecasting through a more thorough understanding of their genesis locations and seasonality. Finally, this research will help deci-sionmakers assess the coastal impacts of tropical cyclones and aid in a better understanding of changes in the frequency and intensity of these storms, which may lead to more robust or updated evacuation plans.

The global tropical cyclone best track dataset will incorporate the 2008 storm year (2007-2008 Southern Hemisphere) into the database; a continued analysis and comparison of previous seasons; and further quality data assessment as needed. The project aims to conduct some education and outreach efforts to make the community more aware of the dataset and its potential applications. In addition, the project will scope out previously undocumented tropical cyclone data that may exist at NCDC. Finally, a website for data dissemination will be developed and maintained.

CHANGES IN EXTREME EVENTS

NCDC will research observed changes in extreme events in the NCDC climate record. This will include investigations of changes in droughts, heat waves, and heavy precipitation. Observed changes will be compared to climate model results in an effort to look at climate change detection and attribution issues. Society recognizes the need to plan for the protection of communities and infrastructure from extreme events of various kinds and engages in risk management. More broadly, responding to the threat of climate change is quintessentially a risk management problem. Structural measures (such as engineering works), governance measures (such

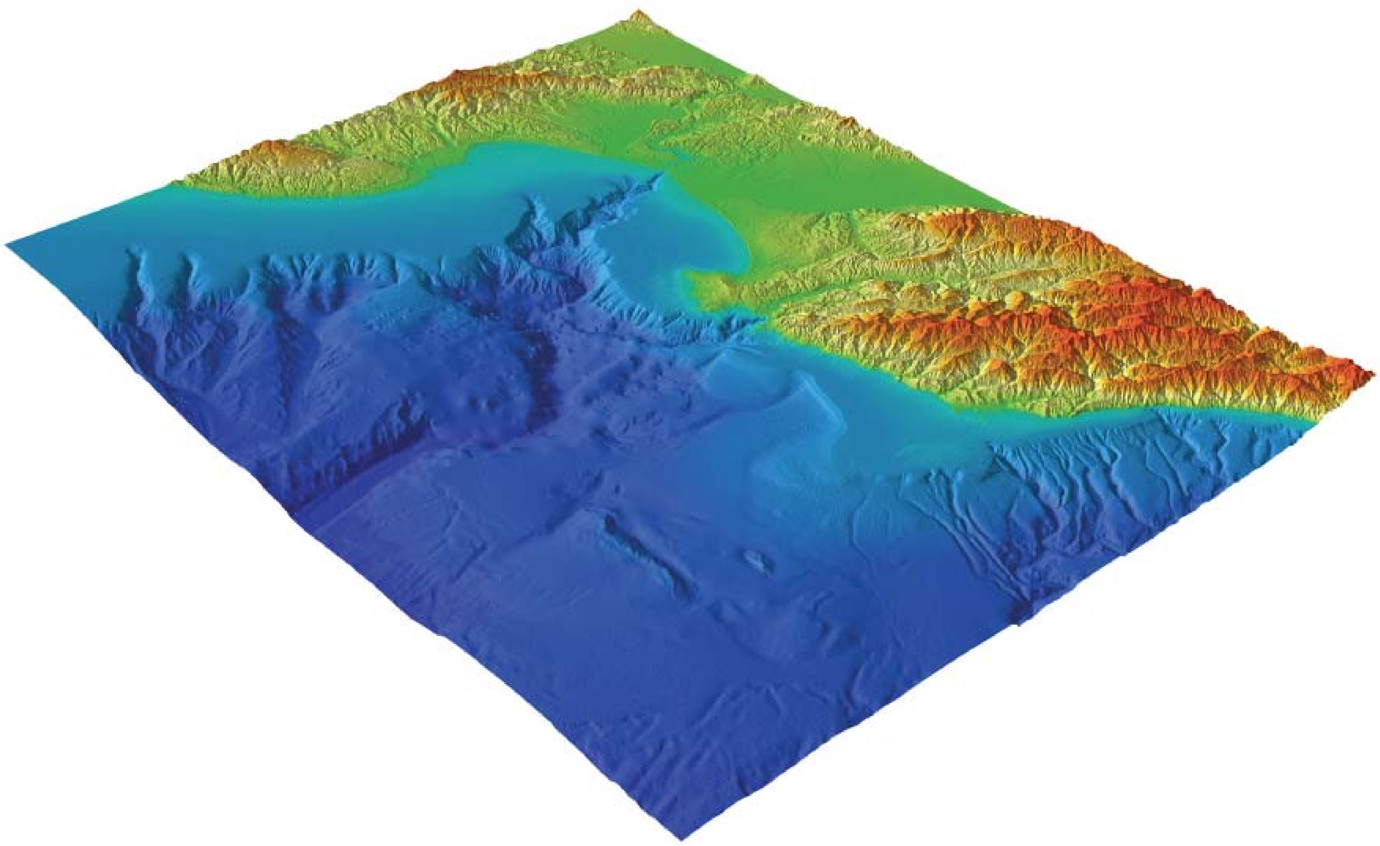


Figure 3-DOC-4 Coastal Digital Elevation Model at 1/3 arc-second for Monterey, California. Used for tsunami forecast and inundation mapping.

as zoning and building codes), financial instruments (such as insur-ance and contingency funds), and emergency measures practices are all risk management measures that have been used to lessen the impacts of historical extremes. To the extent that changes in extremes can be anticipated, society can engage in additional risk management practices that would encourage proac-tive adaptation to limit future impacts. (CCSP 3.3, Chapter 1, www.climatescience.gov/Library/sap/sap3-3 )

## NATURAL HAZARDS COASTAL INUNDATION MODELING AND MAPPING

Since 1900, over 200 tsunami events have affected the coasts of the United States and its territories causing more than 500 deaths. As such, Tsunamis are considered low-frequency but high-impact events that can cause a considerable number of fatalities, inflict major damage, and cause significant economic loss to large sections of the Nation's coastline. To improve the tsunami forecast capability and mitigate the impacts of tsunami and other coastal flooding hazards, the National Geophysical Data Center (NGDC) will continue to develop high-resolution coastal digital elevation models (DEMs) for inundation modeling and mapping. NGDC is also researching how variations in the DEM methodology affect the inundation model results and comparing these results to past tsunami event data. The purpose of the research is to better understand how different data processing methods affect DEM development and to use this knowledge to develop the most accurate coastal DEM generating inundation results validated by historical data. Emergency managers in coastal communities around the United States and its territories use DEMs and the inundation results to guide evacuation planning. Improving DEMs will result in improved forecasts and improved inundation products supporting local community emergency managers and planners, thereby saving lives and money.

GEOMAGNETIC FIELD MODELING FOR IMPROVED NAVIGATION

The NGDC geomagnetism group develops and produces magnetic field models for navigation and pointing, which are used in a multitude of defense and civilian applications. Production of the World Magnetic Model, the standard magnetic model for the Department of Defense (DOD) and the North Atlan-tic Treaty Organization (NATO), is sponsored by the National Geospatial-Intelligence Agency. The geomagnetism group also leads the production and distribution of the International Geomagnetic Reference Field. These main magnetic field models represent approximately 90 percent of the magnetic field, influencing a compass on or near the surface of the Earth. In FY 2009, NGDC will continue research to de-velop improved magnetic models addressing the additional magnetic influences affecting navigation by land, sea, and air. Making use of its extensive holdings of satellite, airborne, and marine magnetic data, NGDC is developing new high-resolution magnetic field models. Recent products include animations of the model results for the change in the magnetic field from 1590-2010, a 3-arc-minute World Digital Magnetic Anomaly Map and the extended magnetic reference model to spherical harmonic degree 720 as shown in the figure below. The NGDC-720 model corresponds to a 15-arc-minute model resolution.

**Hurricane Applications of Lightning Measurements**

The next generation NOAA geostationary satellites starting with the Geostationary Operational En-vironmental Satellite Series R (GOES-R) will have a new capability to measure total lightning. Although ground-based lightning measurements have been available for several years, this will be the first time that this data will be available with high time resolution over the open oceans where hurricanes form and grow. The improvements in the prediction of hurricane genesis and intensification have not kept pace with those for track forecasting. The lightning observations have the potential to provide a new source of information for tropical cyclone forecasting.

Research in FY 2009 will focus on the use of a new ground-based lightning network that can pro-vide some information of lightning activity over the tropical oceans. The World Wide Lightning Locator Network (WWLLN) can provide estimates of only about 25 percent of the lightning activity compared to what will be available from GOES-R, but it will provide a first look at the forecast potential of this new data source. The WWLLN data will be used to examine the relationship between lightning distributions and hurricane formation and intensification in combination with other factors known to be important such as sea surface temperature and atmospheric vertical wind shear.

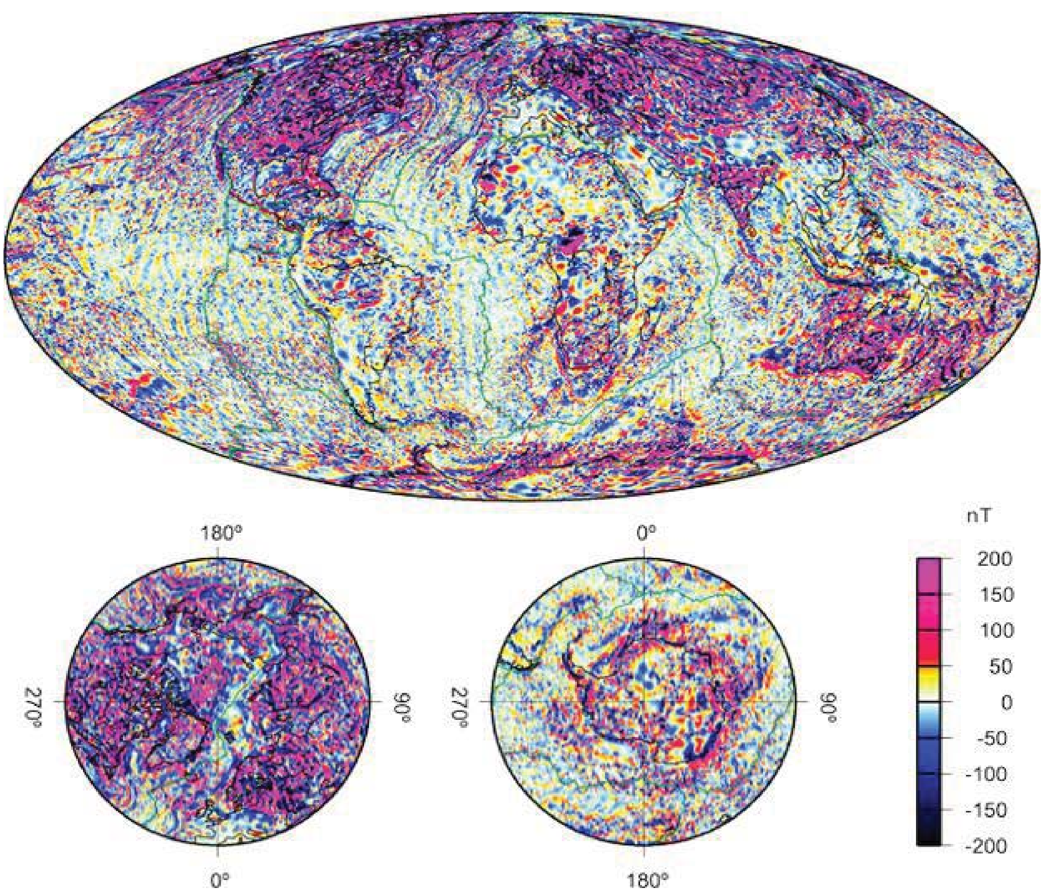



Figure 3-DOC-5. Vertical component of the crustal magnetic field at Earth's surface as given by the NGDC degree-720 model

Figure 3-DOC-6. GOES-12 1 km imagery shows Hurricane Dean near the Yucatan Peninsula

This work has the potential to help improve hurricane forecasts. The ability to better forecast how strong a storm will be when it reaches the coast will help to improve the reliability of hurricane watches and warn-ings, which are important for evacuations and other mitigation activities.

**On the Front Lines of Weather Forecasting: Providing New Satellite Tools to Forecasters**

Weather forecasters depend on a robust set of tools to do their jobs. The accuracy of a forecast is a function not only of the forecaster's knowledge of meteorology and local conditions, but also of their skill in interpreting information from numerical weather forecast models and meteorological observations. Sat-ellite imagery has been one of the most important observations in the forecasters' toolbox for more than two decades. However, raw satellite imagery provides only a very small amount of the information that satellites can provide. The range of satellite products has expanded rapidly over the last decade; these now include detailed characteristics of the Earth's surface (temperature, brightness, snow cover, and vegetation type) and atmosphere (vertical profiles of temperature and humidity, cloud properties, chemistry, and dynamics).

How does NESDIS get these advanced satellite products into the hands of the forecasters? The first step is interacting with the operational forecasters to find out what products will be most beneficial to them. Second, the data providers frequently visit the National Weather Service (NWS) forecast offices to provide online training on new satellite products. Equally important is developing a mechanism to deliver the satellite products so they can be incorporated into the forecasters' operational workflow. NWS forecasters display their model and observational data with the Advanced Weather Interactive Processing System (AWIPS), so getting new satellite products into the forecasters' hands means getting the information into the AWIPS data stream. Efforts in FY 2009 will focus on the transition of new satellite products to the AWIPS environment.

**Precipitation Estimation from Satellites**

Precipitation estimation data from satellites are vital information that supplement surface information measured by ground radars and rain gauges. Research is being performed to improve current satellite precipitation estimation capabilities through a wide range of techniques and satellite instruments. The range of applications using this information is wide and includes disciplines such as weather forecasting and warnings, hydrology, water resources, and climate. For example, in applications that need rapid time updates and fine scale structure, visible and infrared measurements from GOES satellites are used. For those applications that require longer time scales over larger geographical regions, passive microwave measurements from polar orbiting satellites are used.

In FY 2009, research will focus on merging the best properties from all satellite measurements (i.e., all of the sensors and satellites) to improve the precipitation estimates for the entire range of disciplines. In addition, scientists will use data from new sensors on research satellites, such as lightning information and space-borne radars, which will help NOAA develop better algorithms for future satellite missions. Society greatly benefits from this work through the generation of operational satellite products used by NOAA forecasters and scientists, which deliver advanced warnings to the public and longer term predic-tion used by policy makers.

Programs within the Oceanic and Atmospheric Research (OAR) Laboratories support various National Oceanic and Atmospheric Administration (NOAA) meteorological and oceanographic missions. The activities of OAR laboratories provide the innovative ideas needed to improve our understanding of atmospheric, oceanic, and climate science and develop the practical solutions, tools, and techniques that form the basis of improved ocean, weather, water, and climate services.

In an effort to improve national resiliency and better protect lives and property, OAR places special emphasis on improving severe and high impact weather, flooding, hazardous air quality 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. OAR also places emphasis on enhancing our understanding of the global climate system and improving regional decision support tools for climate and weather.

## OFFICER OF WEATHER AND AIR QUALITY (OWAQ)

Located at OAR Headquarters, OWAQ is an important focal point for facilitating and coordinating weather research in OAR and throughout NOAA. OWAQ implements the NOAA's component of the U.S. Weather Research Program (USWRP, http://www.esrl.noaa.gov/research/uswrp/) and the NOAA component of THORPEX: A Global Atmospheric Research Program (http://wwwt.emc.ncep.noaa.gov/gmb/ens/THORPEX.html, from which one can link to the North American and international THORPEX websites). OWAQ also does budget planning for and assists in prioritization of NOAA's weather and air quality research.

### The United States Weather Research Program (USWRP)

The USWRP has been an interagency weather research and transition of research to application program. The member agencies have been NOAA (lead), NASA, NSF, the Navy, and the Air Force. The interagency component of the USWRP has been dormant for the past two years. However, the NOAA component of USWRP has been quite active although the funding levels have been flat. The USWRP funds return to OWAQ from the National Weather Service (NWS) Office of Science and Technology (OST) in FY2009. OWAQ helps plan NOAA USWRP priorities, implements the program, and monitors progress. During the Fiscal Year (FY) 2008-2009 period, NOAA USWRP provided the sole NOAA support for the Developmental Test Center (DTC, http://www.dtcenter.org/index.php) at the National Center for Atmospheric Research in Boulder, CO. The DTC is a test bed for the Weather Research and Forecasting (WRF) community model (http://wrf-model.org/index.php) and is a cooperative venture among NOAA, NSF, the Air Force, and the Navy. The USWRP provides most of the support for the Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information or Societal Impacts Program (SIP) for short (http://www.sip.ucar.edu/). Its mission is to be a clearing house for socioeconomic information on weather, to increase knowledge among the weather community concerning the human and economic impacts of weather, to better determine the value of weather information, and to improve our ability to communicate weather information to all public and private sectors. Major components of the SIP activities include the Weather and Society*Integrated Studies (WAS*IS) workshops and training sessions that bring social science to the meteorological community and vice versa. The SIP also provides the bulk of the U.S. support for the societal and economic research and applications component of THORPEX (see below).

The NOAA USWRP also provides total support for the Joint Hurricane Testbed (JHT, http://www.nhc.noaa.gov/jht/index.shtml) which transitions mature research products from the hurricane research community into operations through improvements in hurricane landfall decision support systems. Recently, the JHT has been emphasizing improving forecasts of hurricane intensity at landfall. In addition, NOAA USWRP has invested in research and transition of research to applications to improve quantitative precipitation forecasts through

NOAA's Hydrometeorological Testbed (HMT, http://hmt.noaa.gov/). The HMT seeks to improve regional precipitation forecasts, particularly for heavy, flooding rains.

THORPEX: A Global Atmospheric Research Program

THORPEX is a 10-year international research program under the World Meteorological Organization that focuses on accelerating improvements in one to 14-day global numerical prediction of high impact weather. THORPEX began in 2004. THORPEX is the weather component of the Global Earth Observing Systems of Systems (GEOSS) and provided the regional and global weather support for the International Polar Year (IPY, 2007-2008). The U.S. representative to the THORPEX international management committee resides in NOAA and NOAA is the lead agency in THORPEX, providing the U.S. funding contribution to the THORPEX international management. Key U.S. agencies that are participating in THORPEX, in addition to NOAA, are NSF, NASA, and the Navy. The main thrusts of U.S. THORPEX are:

- Understanding global scale atmospheric processes and phenomena;
- Improving the science of prediction;
- Providing socioeconomic research and applications;
- NSF, the Navy, and NASA provide the bulk of support for the first bullet. All agencies support the second bullet. The NOAA USWRP and the National Center for Atmospheric Research support activities within the third bullet.

The NOAA/National Centers for Environmental Prediction (NCEP) has developed a North American Ensemble Forecasting system (NAEFS, http://www.emc.ncep.noaa.gov/gmb/ens/NAEFS.html) which is operational as an experimental product and includes the United States, Canada, and Mexico (as a user). NAEFS is an important component of the THORPEX Interactive Forecast System (GIFS) to be available by the end of the THORPEX program period. NCEP is one of the ten operational centers contributing to the THORPEX Integrated Grand Global Ensemble (TIGGE) that provides global ensembles to the weather community. The NOAA USWRP-funded SIP (discussed above) provides U.S. support for the socioeconomic component of THORPEX. In essence, THORPEX underpins all ensemble and probabilistic atmospheric modeling in NOAA. It is the program in which key advances are made in ensemble techniques and atmospheric data assimilation with a significant portion of the applied research being done at OAR's Earth Systems Research Laboratory (ESRL). It also provides the connection on the weather side to climate prediction at the intraseasonal scales that will eventually lead to a seamless weather-climate prediction system.

A major near-term field activity in which the NSF, the Navy, and NOAA are significantly involved is the THORPEX Pacific Asian Regional Campaign (T-PARC, http://www.ucar.edu/na-thorpex/PARC.html). It has three phases: summer, extratropical transition (ET), and winter – spanning FY2008 and FY2009. It is taking place in the Southeast, East, and North Pacific and involves an intensive observing campaign. Most of the Pacific Rim countries are participating, including the United States and Canada. In addition, there is participation by Germany. The summer phase studies the formation, propagation and intensity modulation of West Pacific tropical cyclones. The ET phase studies the transition of tropical cyclones into mid-latitude storms that strike the Northeast Asian and U.S./Canadian West Coast. The winter phase will study the optimum use of targeted observations to improve the forecasts of high impact winter storms on the United States, Canada, and the Arctic. This phase links to the International Polar Year (IPY).

Office of Weather and Air Quality

In FY2008 and 2009, the funds remaining for science support after office operations and staff costs has decreased such that the Special Projects Initiative had to be terminated, at least for now. It supported innovative and competitive research in the OAR laboratories in weather and air quality. OWAQ is supporting the NOAA share of awards under the joint NOAA-NSF Communication of Hurricane Information solicitation. Four awards were made in FY2008 for two and three year performance periods for a total of over $1.5M OWAQ supports about 1/3 of the total. OWAQ also provides partial support for the Natural Hazards Center in Boulder, Colorado, the National Academies' Disasters Roundtable, the Subcommittee for Disaster Reduction of the Office of Science and Technology Policy's Committee for Environment and Natural Resources, and the U.S.-Japan Panel on Wind and Seismic Effects. The OWAQ Director is on the advisory boards for the first two activities and a member of subgroups on the latter two. In FY2009, the USWRP-THORPEX funding moves from the NWS Office of Science and Technology to OWAQ. Although the funds were located in NWS, OWAQ administered the funds and the USWRP and THORPEX projects and will continue to do so after the funds are transferred.

## OBSERVING TECHNOLOGY - ATMOSPHERE

Meteorological, oceanographic, and climate research requires a strong network of observing systems providing data and information and consistent advancements to our observational capabilities. In support of NOAA's mission, OAR supports the advancement of our observing technology through the development and testing of new observing systems, observation techniques, and data ingest and dissemination systems. All OAR observing technology research supports the Global Earth Observing System of Systems (GEOSS) and further establishes OAR as a preeminent leader in meteorological, oceanographic, and climate research.

Numerous OAR laboratories and their related academic and private sector partners are heavily involved in developing new environmental observing system technologies. The ESRL in Boulder, Colorado, 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. ESRL also evaluates new remote-sensing concepts and systems as they apply to specific problems of interest such as the impact of atmospheric rivers on severe west coast flood events. The research activities in HMT-West this year focused on deployment of The National Severe Storm Lab's (NSSL) SMART-R radar system to observe heavy rainfall events over the American River Basin near Sacramento, California. Transition of new forecast products into NOAA operations is accomplished through regional testbeds such as the HMT and the Hazardous Weather Testbed (HWT). Sponsored by the NSSL in Norman, Oklahoma, the HWT also assists in the transfer of new remote observing technologies to the NWS. The Atlantic Oceanographic and Meteorological Laboratory (AOML) in Key Biscayne, Florida, develops, deploys, and manages in situ oceanographic observing systems across the global oceans. The Air Resources Laboratory (ARL) manages the deployment and operation of the Climate Reference Network for NESDIS and operates state-of-the-art chemical deposition measurements in support of model development. This environmental research, development and associated transition of products and services directly support the Nation's forecasting and warning services.

ESRL is taking a leadership role in implementing the International Earth Observation System including the development and testing of Unmanned Aircraft Systems (UAS) for providing global weather and climate observations. ESRL is one of several NOAA Research organizations collaborating with NASA and many external partners in support of this project. The goal is to evaluate the utilization of UASs for improved U.S. and global observing in areas too remote or dangerous for lengthy manned flights, e.g. the polar regions and hurricanes. High and medium altitude, long-endurance UASs (HALE and MALE-class) can fly at remote locations in dangerous flying conditions for long periods. This technology provides many scientific benefits such as sustained global high quality all-weather profiles of atmospheric composition (water vapor, aerosol, cloud water and trace gases), and high altitude vertical resolution and profiling. It also offers a rapid response platform for improved high impact weather forecasts at 1-day to 2-week lead times, and better climate change detection, attribution, and prediction in support of policy decisions. For testing purposes, the HALE-class UAS's integrated sensor package consists of such components as an ocean color sensor and passive microwave sounder, a gas chromatograph and ozone sensor developed by ESRL, a digital camera system provided by NASA, and an electro optical infrared sensor provided by GA-ASI. ESRL is also developing ultra-lightweight sondes to include in the UAS sensor package.

ESRL's Global Systems Division (GSD) has developed GPS-Meteorology, a ground-based research system (GPS-Met) that uses the Global Positioning System (GPS) to measure atmospheric water vapor in real-time, increasing the accuracy of precipitation forecasts in the hourly-updated numerical weather prediction model used by the National Weather Service for high impact weather events. This system collects and processes observations from over 400 GPS-Met stations, owned and operated by NOAA and other government agencies across the United States, and the data is distributed by GSD using a web interface. GPS can be used to calibrate satellite based observations of total precipitable water in the atmosphere, thereby increasing the usefulness of the space-borne sensors. When funds are available, this system will be transferred to National Weather Service operations so that system reliability and maintainability can be ensured and sites expanded for use by NWS forecasters, the research community, and the private sector, as well as incorporated into the weather prediction models. In addition, the GPS-Met observations for water vapor, an important greenhouse gas, are sensor and model independent providing the consistency necessary to support long term monitoring of water vapor for climate applications and a reproducible climate quality data record. The near real-time water vapor measurements from GPS-Met are distributed by the Meteorological Assimilation Data Ingest System (MADIS).

MADIS is a data management system developed and operated by GSD which ingests, integrates, quality controls and distributes surface and upper-air observational datasets to the meteorological community. Among these datasets are an integrated surface mesonet database containing high-frequency, real-time observations from over 30,000 surface stations operated by over 150 different organizations, and an integrated profiler database with observations from 100 wind and temperature profilers operated by dozens of different agencies. In FY09, MADIS operations will begin transitioning to the National Weather Service operations to provide reliable 24/7 data availability.

GSD also continues to move ahead in GOES R3 work in the areas of assisting in the transfer of product improvements to AWIPS, namely looking at current GOES moisture bias and seeing how this compares to GOES R synthetic data using MODIS. In addition, GSD is working with the Cooperative Institute for Research in the Atmosphere (CIRA) in the application of CloudSat data to verify GOES derived vertical cloud structure. GSD and AOML also conduct Observing Systems Simulation Experiments (OSSEs) and Observing Systems Experiments (OSEs), including current collaboration on determining the potential impact of data collected by Unmanned Aircraft Systems (UAS) on the prediction of atmospheric phenomena, including hurricanes (discussed below).

ESRL will continue development of new sensors and innovative techniques for combining observing systems synergistically and economically. 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, ESRL's Physical Sciences Division (PSD) has an active satellite remote sensing group that uses data from various environmental satellites to study air-sea interaction processes, the global hydrological cycle including water vapor and precipitation, and the Earth's radiation budget.

In association with the Center for Environmental Technology (CET) at the University of Colorado, PSD is developing an airborne Polarimetric Scanning Radiometer (PSR) designed to provide higher resolution measurements of sea state quantities including surface winds. PSD/CET is also investigating the possibility of measuring soil moisture by L-band radiometers.

Starting in 2003, PSD and GMD have been working together with the Canadian Meteorological Service and Canadian Network for the Detection of Climate Change (CANDAC) to re-establish a new Arctic Atmospheric Observatory at Eureka, Ellesmere Island, Canada, in North East Canada as a part of the United States. Studies of Environmental Arctic Change (SEARCH) Program. The Canadian Observatory is being designed to mirror many of the cloud, aerosol and radiation measurements that are already made at the GMD Baseline Observatory in Barrow, Alaska that has been in continuous operation for 33 years. Since North East Canada and Barrow, Alaska, are in markedly different Arctic regimes, the long-term measurements from these sites will be complementary in providing information to monitor Arctic atmospheric changes. Long-term data from these sites will be used to improve short-term and long-term forecast models, and improve satellite measurement of meteorological phenomena in the Arctic regions. Along with the National Science Foundation, PSD and GMD are helping to refurbish a historic meteorological station and establish an Atmospheric Baseline Observatory at Tiksi, in the Russian Arctic. This would be the first station of this type in a region that spans 75% of the Arctic littoral. Meteorological data from this newly reinstrumented site will continue a century of data collection that had deteriorated since the collapse of the Soviet Union, and expand measurements to complement those collected at Barrow, Alaska and Eureka, Canada. The high quality of the data to be soon forthcoming from the Tiksi station should considerably enhance Arctic weather prediction and Arctic climate models.

PSD is engaging in a comprehensive observation program to improve operational weather forecast and planned climate model treatments of boundary layer forcing processes. This work centers on development and application of observing technologies for surface fluxes and key boundary-layer variables (profiles of temperature, humidity, wind, and cloud properties). Ship-based measurement systems have been developed and are now used routinely on NOAA research vessels to investigate model accuracies in the marine boundary layer. Recently, land-based systems have been developed and deployed. One point of emphasis is linking observed cloud properties (obtained with mm-wavelength cloud radars and microwave radiometers) to cloud effects on surface turbulent and radiative fluxes (this approach is termed cloud forcing). Ship-based and satellite retrievals of cloud and flux properties are being used. PSD is compiling a large data base to allow climatologically-oriented studies of model parameterizations. Future plans include expanding the observational capabilities to add scanning mm-radar capabilities for investigation of precipitation initiation (a critical issue in triggering deep convection in model domains).

The PSD satellite applications group has developed new techniques for monitoring atmospheric properties over the ocean surface including air temperature and specific humidity. Retrievals of these quantities were improved through novel use of satellite atmospheric sounders in combination with passive microwave imaging radiometers. The products are being applied to improved global estimates of the flux of heat between the ocean and atmosphere. PSD is also producing a new satellite-derived sea surface temperature product through the blending of infrared and passive microwave data. The technique takes advantage of the complementary strengths of the two sensor types. The product has significant meteorological applications through its use as an input to numerical weather forecast and climate models.

NSSL is known for its development of observational capability, both remote and in situ, and in particular for its role in the development of the WSR-88D NEXRAD radar. NSSL continues to improve the WSR-88D software algorithms used by the NWS forecasters and is exploring ways to enhance the WSR-88D hardware using dual polarization techniques under the NEXRAD Product Improvement (NPI) activity. NPI planning, guidance, and funding involves NOAA, DOT/FAA, and DOD/Air Force.

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 signal processing requirements for dual polarization required an initial step of deploying a new Radar Data Acquisition (RDA) unit for the WSR-88D capable of processing the polarimetric signals. The new RDA deployment was completed in 2006.

In 2020, the WSR-88D radars forming this NEXRAD network will be over 32 years old. In about the same time frame, most of the Nation's aircraft surveillance radars will be nearing the end of their design life. Decisions on replacing or repairing and upgrading these National radar assets must be made over the next 10 to 15 years. We are now on the threshold of a revolution in civilian radar capability, enabled by the adaptation of established military radar technology to existing civilian applications, plus new capabilities beyond what current systems can provide. Historically, civilian radars with large rotating antennas like the NEXRAD weather surveillance network and the aircraft surveillance radars used by the Federal Aviation Administration (FAA) evolved from military radar applications. During the past several decades, a new generation of military radars has matured. These electronically scanning phased array radars with no moving parts (rotating antennas) were originally developed to track multiple airborne objects such as aircraft and missiles simultaneously. The unique beam agility, increased resolution, and faster full-volume scan rate of phased array radar can enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

Thus, a single network of multifunction phased array radar (MPAR) units could provide next-generation expansion of our current weather surveillance network, replace the Nation's aging air traffic surveillance radars, and meet homeland security and defense requirements for identifying and tracking non-cooperative craft operating over the U.S. homeland. MPAR will enable continued improvement of the Nation's severe weather warning system. It can provide adaptive sensing for warnings and nowcasts related to severe convective storms and the locally destructive effects of hurricanes (tropical cyclones) after they make landfall. Among the storm phenomena that could be tracked are tornadoes, strong wind gusts, hail, and locally heavy rains responsible for flash floods and mudslides. The enhanced weather surveillance provided by an MPAR network will provide economic benefits to domestic aviation and surface transportation systems. The agility and specificity of its multitasking beams will provide more detailed weather and atmospheric observations for urban meteorology, air quality nowcasts and forecasts, climate variability monitoring and forecasting, wildland fire monitoring and prediction, and atmospheric transport and diffusion modeling. The non-cooperative aircraft surveillance capability of an MPAR network would complement the cooperative surveillance strategy planned for the Next Generation Air Traffic System, while also addressing new craft tracking requirements of the Departments of Defense and Homeland Security. While research at NSSL is establishing the proof-of-principle for new applications of weather radar in these and other areas, the adaptive flexibility of MPAR will be essential in transferring these promising radar techniques to operations.

Because an MPAR network would replace multiple existing networks, it offers an affordable option to the alternative strategy of continuing with the existing civilian radar capability by repairing and eventually replacing aging units. Due to technology breakthroughs in radio frequency components, fueled by the wireless telephony and digital communications industries, the cost of a key MPAR component—the transmit-receive elements in an MPAR antenna—has dropped by orders of magnitude over the past 5 years, and this trend should continue. For a number of reasons, the operations and maintenance costs for MPAR units appear to be a third area of substantial savings relative to continuing to repair and replace current radar units as they age.

Thus, with respect to both capabilities and cost, MPAR is a promising option for meeting the Nation's future domestic radar surveillance needs. Using multiple beams and frequencies that are controlled electronically, NSSL has demonstrated that phased array radar reduces the scan time of severe weather from six minutes for NEXRAD radar to less than one minute, producing quicker updates of data and thereby potentially increasing the lead time for tornado warnings well beyond the current average of 13 minutes.

In support of improved understanding of the changing chemical composition of the atmosphere, the Field Research Division of ARL has continued to refine its constant-level "smart" balloon. The smart balloon is 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. These balloons have been used both for air quality studies, such as the 2006 Texas study, and for hurricane research. The Field Research Division has also developed an Extreme Turbulence (ET) probe for measuring turbulence and surface fluxes in hurricanes. ET probes were successfully deployed into landfalling hurricanes in 2004. The Oak Ridge

Division of ARL 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.

## OBSERVING TECHNOLOGY - OCEAN

In addition to the many weather related observing systems, OAR also dedicates significant time to improving the development, deployment, and monitoring of oceanographic related observing technologies and related data. As part of this effort, AOML manages the deployment of drifting buoys around the world, deploying some 900 new drifters annually and tracking approximately 1250 as part of the Global Drifter Program. Using research ships, ships of the Ship of Opportunity Program (SOOP), and U.S. Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified as 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 in real time to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of sea surface temperature (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.

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

NOAA supports measurements from thermosalinographs (TSGs) that are instruments mounted close to the water intake of research and cargo ships and that continuously measure the sea surface salinity and temperature along the track of the ship. AOML currently operates several TSG transects from three ships of the SOOP in support of the pCO2 Observing System funded by the NOAA Climate Program Office. These TSG data will be used to calibrate and validate observations of the upcoming Aquarius NASA sea surface salinity satellite mission.

NOAA operates and maintains AMVER SEAS 2K, a Windows based real-time ship and environmental data acquisition and transmission system. The AMVER software creates a series of reports that describe point of departure, route, and arrival of a ship. The meteorological reports are transmitted using Standard-C and include ships in a real-time search and rescue database used by the U.S. Coast Guard. The SEAS 2K software acquires atmospheric and oceanographic data and transmits the data in real-time to the GTS and to operational databases to be used by scientists. SEAS 2K is employed on ships of the Volunteer Observing System (VOS), SOOP, and on NOAA, UNOLS, and U.S. Coast Guard vessels. SEAS 2K is now installed on more than 400 ships of the VOS and SOOP and over 200,000 AMVER SEAS meteorological messages are transmitted per year and inserted into the GTS. AOML operates a global XBT Program that utilizes approximately 30 ships of the SOOP and collaborates with international institutions that operate another 30 ships to monitor the global upper ocean thermal structure. This includes low and high density deployment modes. TSG and XBT data are placed in real-time onto the GTS and are being used to initialize weather and climate forecast models.

Together with NOAA's Pacific Marine Environmental Laboratory (PMEL), Brazil, and France, AOML contribute to the Pilot Research Moored Array in the Tropical Atlantic (PIRATA), a project designed as an extension of the Tropical Atmosphere Ocean (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, inter-annual and longer time scales. The PIRATA Array consists of 20 ATLAS moorings similar to those deployed in the Pacific, including moorings established within the hurricane genesis region of the Atlantic, which will allow for a better understanding of ocean-atmosphere interactions on hurricane development and enhanced predictions of hurricane formation. Four ATLAS moorings were recently deployed as the eastern extension of the PIRATA array. The moorings were built by PMEL and are similar to those deployed in the Pacific. Planned expansion of the PIRATA array into the hurricane genesis region of the Atlantic will allow for a better understanding of ocean-atmosphere interactions on hurricane development and enhanced predictions of hurricane formation.

In an effort to better understand and forecast climate, OAR has been deploying a global array of profiling floats since 2000. The broad-scale global array of temperature/salinity profiling floats, known as Argo, has already grown to be a major component of the ocean observing system with a deployment of 3000 floats. Argo floats are free-drifting profiling floats that spend most of their life "parked" at 1,000 or 2,000 meters depth in the ocean, regularly surfacing to make temperature and salinity profile measurements and providing those observations in real-time. As of June 2007, 2856 Argo floats have been deployed (95% complete). AOML is the U.S. Argo Data Assembly Center and the South Atlantic Argo Regional Center, in charge of all U.S. Argo deployments in the Atlantic. The Argo array is part of the Global Climate Observing System/Global Ocean Observing System (GCOS/ GOOS) and is a major contributor to the WCRP's Climate Variability and Predictability Experiment (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE). Combined with satellites, Argo data provides a quantitative description of the changing state of the upper ocean and the patterns of ocean climate variability from months to decades, including heat and freshwater storage and transport.

The Tropical Atmosphere Ocean/TRIangle Trans-Ocean buoy Network (TAO/TRITON) array consists of approximately 70 Autonomous Temperature Line Acquisition System (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 GCOS, and the GOOS. The array is supported by the United States (NOAA) and Japan (JAMSTEC), with JAMSTEC responsible for the TRITON moorings west of 165oE longitude and NOAA responsible for the 59 moorings along and east of 165oE. Responsibility for maintaining the TAO Array has been transferred to the NWS/National Data Buoy Center, and the PMEL continues to be involved by providing the instrumentation for the TAO surface moorings. 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 third research array, the Indian Ocean Moored Buoy Array, was initially established in 2000 by Japan, and later joined by India, the United States, Indonesia, and France. The U.S. contribution to this array utilizes PMEL's ATLAS moorings, similar to those in the Pacific TAO and PIRATA Arrays. The Array continues to expand toward its eventual goal of 47 sites and is designed to conduct research on the seasonal monsoonal variability in the Indian Ocean, its interactions with ENSO, and the Indian Ocean Dipole, an El Niño-like phenomenon in the Indian Ocean.

As part of the backbone for the Integrated Ocean Observing System (IOOS), OAR supports the national ocean observation backbone through 29 deployed or planned operational ocean moorings as part of the Ocean Reference Station network. The operational ocean moorings provide measurements of high quality air-sea fluxes of heat, moisture, and momentum that will be used to make regional assessments of flux components from numerical weather prediction models and satellites. A partnership with the National Science Foundation's ORION program will greatly enhance the capacity of the network.

HIGH IMPACT WEATHER RESEARCH

In addition to research and development of observing systems and related technology, OAR also focuses on ways to improve our understanding and the predictability of severe weather systems and their associated hazards. Several regional testbeds have been created to research these hazards including the Hydrometeorological Testbed (HMT) and Hazardous Weather Testbed (HWT). PSD, GSD, NSSL and other partners participate heavily in these testbeds. Several storm systems were observed and unprecedented data sets were collected in FY2006 and FY2007. GSD has been a collaborator in the HMT from 2005 to the present. This has involved configuring high resolution ensembles, probabilistic quantitative precipitation forecasts, evaluation, and debiasing and calibration to better frame the uncertainty in heavy rain events. This has applications in warning on forecast and integrating into decision aids. Over the last two years 18 Intensive Observing Periods have been supported and forecasts verified. The program has demonstrated the ability to produce high resolution probabilities in operationally critical thresholds of 1-2 inches in 6 hours for the west slope of the Sierras.

NSSL has developed a unique and vibrant collaboration with the operational forecasting community, which has recently been formalized with the establishment of the HWT. The mutual interests of forecasters from the NOAA Storm Prediction Center, researchers from NSSL and ESRL, and collocated joint research partners from the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) inspired the formation of the HWT. The testbed's activities have been varied, including activities such as daily map discussions involving imminent severe weather, loosely-related research projects involving 2-3 collaborators, and periodic intensive collaboration periods with larger groups. But the cornerstone of the testbed has been the SPC/NSSL Spring Program, a series of annual experiments that attracts 50-60 researchers and forecasters to Norman each year.

The premise of each spring experiment within the Spring Program is to provide forecasters with a first-hand look at the latest research concepts and products, while immersing research scientists in the challenges, needs, and constraints of front-line forecasters. In practice, this program gives forecasters direct access to the latest research developments while imparting scientists with the knowledge to formulate research strategies that will have practical benefits. The end result is not only better severe-weather forecasts, but important contributions to the scientific literature as well. Science partners in recent spring experiments have included NCAR, NCEP/EMC, OU/CAPS, and numerous academic centers.

The NSSL focuses on research to better understand such hazards as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms with the goal of helping the NWS improve forecasts and warnings. 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. NSSL continues to focus on research and development of the NWS WSR-88D radar program and to develop techniques, in cooperation with the NWS, to forecast and warn of weather hazards to aviation and the general public. NSSL's research includes assessment and improvement of numerical models to forecast severe weather systems.

NSSL's vision for the warning decision process continues to evolve as scientists and engineers work toward integrating the next generation radar (MPAR) and storm-scale numerical models to create a storm-scale prediction capability for the NWS. Within the next decade, NSSL envisions operational units using a "Warn on Forecast" methodology, e.g., a forecaster will use thunderstorm-resolving computer models for severe weather warnings in the same way as he/she does today with the current Doppler radar systems. NSSL believes that these enhancements to the operational weather capability will lead to a more accurate warning system which increases lead time and provides probabilistic information that enables the public to take the best reasonable action during a severe weather event.

NSSL works with the FAA Aviation Weather Research Program (AWRP) to develop weather radar applications that enhance the safety and efficiency of the aviation community and the National Airspace System. Work is focused on both convective weather and winter weather, with special attention to treating all WSR-88D radars within the continental United States as a single network. Such treatment allows NSSL to produce a single, authoritative 3-dimensional grid of radar data. Intensive research is also directed to polarimetric radar applications unique to aviation needs. Examples include winter time quantitative precipitation estimation, detection of icing conditions, and data quality issues unique to FAA users.

The NSSL is collaborating with the NWS Office of Hydrologic Development (OHD) and the Office of Climate Weather and Water Services in the development, testing, and research-to-operations of a 'state of the science' approach to quantitative precipitation estimation (QPE) and short-term precipitation forecasts (QPF). The goal of this cross agency collaboration is to increase warning lead times for the detection and prediction of flash floods and river flooding. This effort is part of the Advanced Hydrologic Prediction Services (AHPS), which is an essential component of the NWS Office of Climate, Water, and Weather Services. The research and development into QPE and QPF is being afforded by FAA and NCEP collaboration towards the integration of radar networks into seamless high-resolution three-dimensional mosaics for use in aviation safety and atmospheric model data assimilation. NSSL has established the infrastructure and techniques for ingesting domestic and international weather surveillance radars, along with integrating satellite and surface observations, to facilitate research and development toward advance monitoring of the Nation's fresh water resources. The vision and objectives of the research is to improve the capability to effectively manage the Nation's fresh water resources and to mitigate the social and economic impacts of flooding through timely and accurate detection and prediction of precipitation.

NSSL continues to lead a project called CI-FLOW (Coastal-Inland Flood Observation and Warning) that uses NSSL's multi-sensor rainfall estimates to drive an NWS distributed hydrologic model that predicts stream flow to help NWS improve flash flood warnings. CI-FLOW is the primary component of NOAA's new Integrated Water Resource Services project called Coastal, Estuary Resource Information System (CERIS). In addition to the stream flow prediction, stream flow data from predictive models are used to drive three models run by academic collaborators at N.C. State University: a water quality model, estuarine model, and a storm surge model. This system of coupled models, when fully integrated, can be used for land-use studies, algal bloom studies, pollution studies, and inundation studies of land-falling tropical systems.

OAR will continue to transfer knowledge of Doppler radar applications, severe weather systems, forecast and warning improvements, and heavy rainfall events; much of the transfer is through courses at the NWS training center and through the HWT at the new National Weather Center in Norman, OK. 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.

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. GSD develops and evaluates Aviation Impact Variable (such as icing, turbulence, ceiling and visibility, convective weather, volcanic ash) algorithms and decision tools for NWS forecast offices and FAA traffic management environments, including commercial and civil aviation. Specifically, GSD 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. In FY09, GSD will assist the NWS in evaluating development of the Advanced Weather Interactive Processing System (AWIPS) II system and will prototype enhancements for AWIPS II incorporating new science such as uncertainty grids for weather parameters. GSD has developed an AWIPS thin client system, FX-Net, which is used extensively by the NWS Incident Meteorologists in the field and agencies responsible for wildland fire fighting. In FY09, development will begin to couple an atmospheric prediction model with a fire spread model in order to address the wildland-urban interface fire spread problem. FX-Collaborate is an AWIPS capability developed by GSD that allows forecasters in different geographical locations to interact in real-time to develop a forecast. FX-Collaborate is being used to support decision aids for aviation weather (Volcanic Ash Coordination Tool, FAA traffic management units coordination, NWS Center Weather Service Units coordination with the FAA) and for weather effects and early warnings in response to homeland security events (Geo-Targeted Alerting System and UrbaNet). Also, in FY09, GSD will continue to provide support to NWS aviation-support facilities in Ft Worth, Anchorage, and Leesburg, VA using FX-Collaborate applications. NSSL is collaborating with NWS and GSD to integrate some of NSSL's advanced single and multi-radar display capabilities into AWIPS.

The NextGen Air Transportation System, supported by the FAA, is helping to develop the capability to move relevant observation and forecast information into and out of a virtual weather database called the 4D-Cube. Data quantity, update frequency, timeliness, and latency are important performance considerations for this capability, called NextGen Network Enabled Weather. In addition, a Network Enabled Verification Service will help determine the content of a subset of the 4D-Cube data, to be called the Single Authoritative Source (SAS). The SAS will provide a common weather picture for all aviation decision-makers using weather information.

GSD 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); Tropospheric Aircraft Meteorological Data Relay (TAM-DAR), WSR-88D Doppler radars; and weather satellites, especially Geostationary Operational Environmental Satellite (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 (LAPS) which employs conventional analysis methods and 3-D variational methods to provide highly detailed analyses and coupled numerical models (WRF-NMM and WRF ARW) to provide forecasts over areas hundreds of meters on a side. Efforts include methods for surface boundary detection and tracking, convective initiation, and heavy rain forecasting with a hydrologic emphasis for the HMT and HWT. LAPS has been installed for use in the US Space Centers for launches, in a DOD program for precision airdrops, and many other venues requiring high resolution weather predictions. GSD is working with the Department of Homeland Security to implement a high resolution forecast and dispersion system for major urban areas. LAPS is an integral part of an emerging wild fire forecasting system that assimilates airborne and ground sensor data and make short range predictions of the atmosphere in the vicinity of the fire. In FY09 and beyond, LAPS will work to effectively couple fire scale atmospheric models with simple and complex fire behavior models to provide critical decision support to incident commanders and land managers. LAPS will be transitioning to a more flexible 3-D variational format within the context of the Space-Time Mesoscale Analysis System (STMAS) that better exploits 4-D databases for optimal resolving of important meteorological systems.

Coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). Emphasis has shifted from the study of terrain effects on West Coast weather to coastal wind and air-sea interaction research in the Gulf of Alaska. Research partners include the NWS Forecast Office in Juneau, AK with financial support for the research being provided by NSF and NOAA/NOS through the Global Ocean Ecosystem Dynamics (GLOBEC) program.

## MESOMETEOROLOGY AND PRECIPITATION FORECASTING AND WARNING RESEARCH

In support of NOAA's goal of protecting lives and property, OAR contributes to the development of techniques to improve short term forecasters of significant weather events. Through detailed case studies and regional climatologies, NSSL and ESRL scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storm complexes. Example programs whose data have been and continue to be analyzed include (1) the Severe Thunderstorm Electrification and Precipitation Study (STEPS) in 2000, (2) the International H2O Project (IHOP), (3) the Thunderstorm Electrification and Lightning Experiment (TELEX) 2003 and 2004, and (4) the annual collaborative severe storm research by NSSL, the NWS/SPC, the Norman Weather Forecast Office, and collaborators through the Hazardous Weather Testbed Spring Program.

Other NSSL studies underway are focused on the precipitation structure of large storm systems (mesoscale convective systems), the interactions between meso-convective 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. Findings from these research activities lead to supporting the forecasting of a variety of high impact weather events.

NSSL will continue to investigate various model convective parameterization schemes, along with techniques to improve model initialization through four-dimensional data assimilation. Advances continue in numerical simulation and forecasting at mesoscale and stormscale resolutions. Current research is using data assimilation by ensemble Kalman Filter method, as well as lightning data assimilation, to improve forecasting of convection. At stormscale, pure simulation is also employed for improving understanding of dynamics, microphysics, and lightning. Toward the goal of improving operational mesoscale model and human forecasts of storms and their environments, NSSL researchers investigate the convection initiation (CI) process and the types of observations required to represent CI and storms in both research and operational mesoscale analysis and forecast model systems.

The U.S. Southern Great Plains region is an optimal location due to existing experimental and operational facilities, strong variability in moisture, and active storms and convective systems providing most of the warm season precipitation east of the Rocky Mountains. Recent studies report a new method for objectively combining diverse radar and in-situ measurements to obtain internally consistent analyses of boundary layer evolution and cloud formation with application to cases that illustrate the impact of drylines and cold fronts on the CI process. Given sound conceptual models of the CI process, forecasters in turn can interpret available observations more precisely to improve specificity and accuracy of storm forecasts. Another recent study reports the potential improvement of mesoscale model initialization via the assimilation of all types of real-time total and cloud-to-ground lightning observations to improve representation of ongoing convection and its integrated effects on model initial conditions.

NSSL has also made advances in the interpretation of lightning data. This information will point to new ways for the National Weather Service to use lightning observations to improve forecasts and warnings of hazardous weather. NSSL operates state-of-the-science facilities that include the Oklahoma Lightning Mapping Array (OK-LMA) and the University of Oklahoma Westheimer Airport radar in Norman, which is a WSR-88D radar modified with polarimetric parameters to provide information about the particle size and water phase of precipitation. The OK-LMA is a network of 11 stations in central Oklahoma that continuously maps in high space and time resolution the structure of all types of lightning in three-dimensions out to a range of 75 km and in two-dimensions out to a range of 200 km. All the technology advances and research findings are aimed at NSSL's contribution to advances in forecasting high-impact weather events.

NSSL is working with the NWS Storm Prediction Center (SPC) to improve the nation's ability to forecast severe weather and to enhance severe winter weather guidance products. A major forecast challenge for SPC forecasters is severe weather generated from elevated convection. Recent collaborative research shows the spatial and temporal distribution of such severe weather reports and begins to provide insight into processes that would improve our ability to forecast these events.

The Norman meteorological community consolidated its diverse workforce into a common building in 2006. Numerous groups are adopting the collaborative spirit and innovative approach of the HWT. At the same time, the HWT is expanding to embrace these groups and provide the framework for development and implementation of new technologies in different areas, particularly those focusing on shorter-timescale forecasting challenges. For example, NSSL's Severe Weather Warning Applications and Technology Transfer (SWAT) team and the NWS Norman WFO are stepping into important leadership roles within the HWT.

NSSL anticipates that the proof of concept established through the annual NSSL/SPC Spring Program and the early years of the HWT will play an important role in bringing together the diverse elements of the Norman meteorological community and like-minded meteorologists from across the country. Congress provided seed funding to help foster a collaboration between the HWT, the University of Alabama at Huntsville, and NASA's Short-term Prediction Research and Transition Center (SPoRT), a joint center staffed by NASA research meteorologists also located in Huntsville, and the Huntsville WFO. The Norman meteorological community in Oklahoma is being referred to as HWT/Norman and the groups in Alabama are being referred to as HWT/Huntsville. Working together, these groups will strengthen the nation's collective knowledge and understanding of these hazardous convective events.

Along with NCAR, NCEP, and the university community, GSD has collaborated on the development of the Weather Research and Forecasting (WRF) model. The WRF model has 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. GSD will replace the Rapid Update Cycle (RUC) model with the WRF Rapid Refresh model by 2009, updated hourly and extended to Alaska, Puerto Rico, and the Caribbean Sea.

GSD scientists lead work with other scientists from NOAA/ESRL toward development of a new global model including use of the adaptive isentropic-sigma hybrid vertical coordinate successful with the RUC model, accurate finite-volume horizontal advection, and use of an icosahedral horizontal grid. ESRL is collaborating with NCEP's Environmental Modeling Center (EMC) and the Geophysical Fluid Dynamics Laboratory (GFDL) on development of the FIM model (Flow-following Finite-volume Icosahedral Model).

OAR's Air Research Laboratory (ARL) research on the coupling between the air and the surface and the surface energy budget provides key information for improving numerical models. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as emissions from sources like volcanoes, industrial enterprises, and nuclear accidents. In recent work, ARL is adapting a new system developed to forecast dispersion of smoke from forest fires in a study performed in collaboration with the Association of South East Asian Nations, the U.S. Forest Service, and The Mediterranean Centre for Environmental Studies Foundation. The present program will provide interim products to the joint NOAA-EPA Air Quality Forecasting Program to improve smoke dispersion estimates in the particulate forecast model.

## TROPICAL ATMOSPHERIC RESEARCH

The Tropical Dynamics and Climate Program of the Physical Science Division (PSD) is using precipitation profilers to study the structure, evolution and variability of precipitating cloud systems in the tropics and elsewhere. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. A recent focus of research with profilers has been to provide ground validation research in support of satellite precipitation measurement missions such as the NASA Tropical Rainfall Measuring Mission (TRMM). These satellite observations have provided important information on the vertical structure and temporal evolution of precipitating cloud systems during TRMM Ground Validation field campaigns. Collaborating with other TRMM researchers, the observations made during the field campaigns use profilers to calibrate scanning radars used for TRMM ground validation research and to retrieve dropsize distributions and related precipitation parameters of interest to the TRMM Science Team. Validation of dropsize distributions used in algorithms is key to improving the retrieval of rainfall estimates from the TRMM satellite data. The profiler-based precipitation research described above also can be used to provide calibration of NEXRAD scanning radars as has recently been demonstrated for Melbourne, Florida. In related activities, PSD is carrying out hydrometeorological studies in collaboration with the NWS in demonstrating the value of hydrome The Atlantic Oceanographic and Meteorological Laboratory's (AOML) Hurricane Research Division (HRD), together with researchers at the GFDL, ESRL, and NESDIS's Satellite Applications and Research (STAR) division make up the NOAA core capability for hurricane research and development and is envisioned to be a major part of the new NOAA Hurricane Forecast Improvement Project (HFIP). HFIP builds upon and draws much of its NOAA expertise from these core research and development capabilities and is driven by the operational needs of the NWS. Within the NWS, the National Hurricane Center (NHC), the Central Pacific Hurricane Center, and the hurricane-modeling group at the Environmental Modeling Center (EMC) comprise the NOAA core operational hurricane capability.

The HFIP is a new effort to develop a unified 10-year plan to improve one to five day tropical cyclone forecasts, with a focus on rapid intensity change. HFIP is only feasible because of the core research and development capabilities at HRD, AOML, GFDL, and ESRL. The objectives of the HFIP are to coordinate hurricane-related research and development within NOAA (such as those mentioned above), and to broaden the interaction of the outside research community in addressing NOAA's operational hurricane forecast needs. The goals of the HFIP are to improve the accuracy and reliability of hurricane forecasts; to extend lead-time for hurricane forecasts with increased certainty; and to increase confidence in hurricane forecasts. These efforts will require major investments in enhanced observational strategies, improved data assimilation, numerical model systems, and expanded forecast applications based on the high resolution and ensemble based numerical prediction systems. The expected outcomes of the HFIP are high quality information with associated probabilities on high impact variables such as wind speed, precipitation, and storm surge. This will be achieved by reducing the average errors of hurricane track and intensity forecasts by 50%, improving the skill in forecasting rapid intensity changes (both increases and decreases), and by improved storm surge forecasting. The benefits of HFIP will significantly improve NOAA's forecast services through improved hurricane forecast science and technology. Specific metrics include:

- Reduce average track error by 50% for Days 1 through 5.
- Reduce average intensity error by 50% for Days 1 through 5.
- Increase the probability of detection (POD) for rapid intensity change to 90% at Day 1 decreasing linearly to 60% at Day 5, and decrease the false alarm ratio (FAR) for rapid intensity change to 10% for Day 1 increasing linearly to 30% at Day 5.
- Extend the lead time for hurricane forecasts out to Day 7.

While improving the POD and FAR for rapid intensity change within 1 day of landfall is a high priority, given the uncertainty in track forecasts of landfall, these improvements are needed at all lead times over the entire life span of the storm system.

NOAA needs to address two other areas to meet the HFIP goals: (1) expand the forecast tools and applications to the operational forecasters; and (2) develop a capability to evaluate observing strategies in order to inform NOAA of significant investments in new observing systems. Regarding the development of forecast applications, HRD has developed a number of these applications with support from programs such as the Joint Hurricane Testbed (JHT) intended specifically to improve the transition of research to operations. Under the USWRP and its participating agencies, OAR, NWS, and NESDIS established the Joint Hurricane Testbed (JHT) at the Tropical Prediction Center in Miami, Florida in 1999. This testbed is where the hurricane research is evaluated for operational use and those research products passing the test will be handed off to operations. HFIP envisions 10 times the current number of projects in order to meet the goals and metrics outlined in the plan.

NOAA is supporting a number of Observing Systems Simulation Exercise (OSSE) studies to provide critical guidance on the optimal composite observing system for hurricane monitoring and prediction, including such future observing systems as those flying on UAS. The idea of an OSSE is to create a simulated atmosphere so that observation impact can be directly evaluated against the "true atmosphere". To execute this OSSE, not only must the future observations be simulated, but also the other operational observing systems, from a "nature run". The hurricane UAS OSSE is utilizing a global Nature Run developed by the European Center for Medium-Range Weather Forecasts (ECMWF) with ~40 km spatial resolution. Satellites currently provide most of the observations of a hurricane's environment, whereas much of the inner core observations are produced by the NOAA P-3 or G-IV aircraft. It is a formidable challenge to develop an OSSE, which explains why an international, multi-agency working group that includes NCEP/EMC, GSD, NASA, the Joint Center for Satellite Data Assimilation (JCSDA), and ECMWF are all involved in this effort. The numerical prediction model (different from that used to create the Nature Run) provides forecasts by assimilating the synthetic observation datasets into the model's initial state. By examining the forecasts made with assimilated synthetic data against the "true" atmosphere, and compare the results to forecasts made without such observations, the impact from the observations can be evaluated.

To meet NOAA's UAS program requirements, "Quick-OSSE" and OSE will be performed by GSD in collaboration with AOML for assimilating into high-resolution regional hurricane models the actual atmospheric data collected in the past by UAS aircraft (such as with hurricanes Noel and Ophelia). An OSE allows for the systematic impact of each contributing observing system to be evaluated by making "data denials" to the model's initial state. Thus, OSE allows determination of the forecast impact after the data is actually collected, as opposed to an OSSE, where an optimum sampling strategy can be explored in a controlled environment before aircraft are sent out into the field to take the measurements. Clearly, an OSSE permits testing of multiple flight strategies, sampling rates, and payload options to arrive at an optimized solution, whereas an OSE can only deal with the actual measurements taken from a flight made with a given payload. There is a middle ground between these two extremes – that being the Quick-OSSE approach, in which a very high-resolution regional numerical simulation is first made for a given case from the past in which actual data are available, but first by withholding the data from the model. Then, simulated data are extracted from this real-data simulation and assimilated into a lower resolution model that is different from the one chosen for the control run (e.g., different versions of the WRF model could be used for this purpose). A wide variety of sampling and payload options can thus be tested. The comparisons allow for some measure of guidance about improvements that could be made in the future testbed deployments of aircraft and sensor payloads.

HRD's capabilities are based on the use of in situ and remotely-sensed data collected by aircraft, satellites, and buoys, and computer model simulations of the inner core of tropical cyclones and their surrounding environment to improve track and intensity forecast guidance. These observations are primarily collected during the hurricane season using two NOAA turboprop aircraft and a Gulfstream-IV jet operated by NOAA's Aircraft Operations Center (AOC). The field program is used to carry out scientific experiments designed to address the goals stated above. Data sets gathered on these flights in all stages of the storm's lifecycle are used to support operational needs and form the cornerstone of research in HRD. Because of this extensive field experience, HRD scientists are recognized internationally for their knowledge of tropical cyclones, as well as their expertise in technological areas such as airborne Doppler radar, dropsondes, cloud microphysics, and air-sea interaction, to name a few. These assets make HRD unique worldwide capability.

Much of the research at HRD is going to improve forecasts of hurricane intensity change, however HRD scientists are also actively engaged with scientists in the other AOML divisions in projects related to seasonal hurricane forecasts, the impact climate change has on hurricanes, and the impacts hurricanes have on life and property. HRD also coordinates its programs with other NOAA organizations, e.g., AOC, NESDIS, and NCEP, in particular with EMC and NHC. A high priority since 2005 is the NOAA Intensity Forecast Experiment (IFEX) developed through a partnership involving HRD, TPC, EMC, and NESDIS. The goals of IFEX are the collection of data to directly aid the development and evaluation of the next generation operational Hurricane Weather Research Forecast (HWRF) model. HRD also maintains active research programs with, and receives funding from other governmental agencies, and arranges cooperative programs with scientists at NCAR and numerous universities. HRD's strengths provide NOAA with the capability to address the HFIP plan.

PSD's effort is focused on observation and parameterization of air-sea flux processes. Hurricanes are driven entirely by surface heat flux and their intensity is predominantly determined by friction at the surface (momentum flux to the ocean currents and waver). Recently PSD has been working with EMC to transition the PSD sea spray/flux parameterizations to HWRF. Historically hurricane models have used unrealistic surface flux parameterizations in order to achieve the observed central pressure – maximum wind speed relationship. However, as fully coupled (air –ocean –wave) models come online, it will be necessary to incorporate more realistic and physically based flux parameterizations. PSD is also working with ARL and HRD to advance critical observational technologies for research on surface properties, fluxes, and atmospheric boundary layer dynamics. This includes development of hardened surface-based in situ flux and sea spray sensors to mm-wavelength radars and GPS reflection systems for use on the NOAA P-3's and/or UAS platforms.

Via THORPEX funding (see page 3), PSD scientists have developed an efficient global ensemble Kalman filter (EnKF) data assimilation technique that has demonstrated in preliminary experiments the ability to initialize hurricanes much more accurately than existing data assimilation techniques used in NOAA. The current operational NOAA technique utilizes 3-dimensional variational analysis (3DVAR) and “vortex relocation.” This technique has not been able to initialize hurricane vortices with sufficient intensity, and the analyzed vortex is often not preserved in short-term forecasts to the same extent that it is preserved under the EnKF, i.e., the forecast is subject to much less “spin-up.” PSD is working in cooperation with GSD and HRD on further testing of EnKF techniques in global and regional models. Other data assimilation strategies are also being investigated jointly by GSD and HRD, including use of the NCEP version of the Grid-point Statistical Interpolation (GSI) for the HWRF model, the STMAS 3DVAR technique, and possible hybrid 3DVAR-EnKF approaches. One of the goals of this research is to ensure that the inner hurricane core data collected by the NOAA aircraft and other systems are represented properly in the HWRF model initial state.

GSD participates in a large number of modeling and data assimilation activities relevant to hurricane prediction beyond the OSSE and collaborative data assimilation studies mentioned above, including being a co-partner with the National Center for Atmospheric Research (NCAR) in the Developmental Testbed Center (DTC). The activities of the DTC include testing of select codes from the Weather Research and Forecasting (WRF) model for possible elevation to Reference Code, maintaining and supporting this Reference Code to the community, and testing and evaluating improvements made by the community in order to accelerate the infusion of new numerical weather prediction capabilities into operations. The DTC has recently begun working closely with NCEP in supporting the operational HWRF modeling system to the community. In addition, the DTC has extensive interactions with members of the hurricane research community, notably with HRD and PSD, related to new NWP technologies that show promise for improving hurricane prediction. HWRF consists of the NCEP version of the WRF model, known as the Nonhydrostatic Mesoscale Model (NMM), coupled to an ocean model (the Hybrid Coordinate Ocean Model, HYCOM), and a wave model used by both NOAA and the Navy (WAVEWATCH III). Quite recently, the WRF-NMM model component of HWRF as well as the NMM-based Hurricane Research System developed by AOML, have been ported to DTC supercomputer facilities at GSD and NCAR to enable NOAA Research to be able to work as a community with these hurricane forecast systems.

GSD is also participating in an experimental use of a very high-resolution ensemble version of its finite-volume, icosahedral global model (FIM) to address the need to improve medium-range hurricane track forecasts. This is being done to address fundamental issues of environmental predictability of tropical and other high impact weather systems under NOAA’s Environmental Modeling Program, and to develop the necessary modeling techniques to improve NOAA’s capability to accurately predict the evolution of these systems. Significantly improved forecasts of hurricane track and intensity out to 5 days and beyond would greatly improve the risk-based decision making necessary for the protection of life and property along the U.S. coastline from intense landfalling hurricanes. The purpose of running an ensemble forecast system is to attempt to improve both the accuracy and reliability of the forecast to greatly reduce the costs and disruptions due to emergency response. Large increases in NOAA supercomputing capabilities are dictated in significant ways by these needs, resulting in proposed R&D and operational computing advances by FY2011.

Three important activities begun in 2008 under the HFIP are the high-resolution modeling workshop and test plan coordinated by the DTC and the high-resolution predictability research effort utilizing the Texas Advanced Computing Center (TACC), and the development of an observing strategy analysis capability for the high-resolution regional hurricane model utilizing a number of data assimilation and inner core observing system simulation techniques.

The HFIP high-resolution modeling workshop coordinated by the DTC was held at NHC in March 2008, and the test plan developed from the workshop brings together seven model development teams from OAR (AOML, ESRL, GFDL), other Federal agencies (NRL, NASA), and academia (NCAR, TAMU, Wisconsin) to demonstrate the potential benefits of high-resolution (≤1 km horizontal resolution) hurricane models. Each team agreed to “freeze” all variables that may contribute to the quality of the intensity forecasts except horizontal grid resolution, which will be tested at three resolutions: 1-2 km, 3-5 km and about 9 km. Thus the potential benefit of higher grid resolution can be evaluated for each of the participating teams by comparing their test runs at varying resolutions. Given the diversity of the model configurations overall, there is an excellent opportunity to create a multi-model ensemble metric for evaluation. Each team will run their model configuration for 60 cases from 10 storms selected by the NHC forecasters. “Truth” data for verification will come from the operational database at NHC including the final operational best track and archived tropical cyclone data. A verification team, made up of operational and research scientists, developed an agreed upon set of metrics for all simulations. All teams agreed to provide as many simulations as possible between September 2008 and February 2009. The verification results will be tabulated and presented to the teams at another workshop in March 2009. As part of this test a team from HRD and GSD are working together to develop a hurricane research system based on the WRF-NMM version 3 utilizing many of the operational physics packages.

The goal of the high-resolution predictability research at TACC is to make substantial progress on establishing the operational value of higher resolution modeling (global and regional - including ensembles) to improving overall forecast performance, one of HFIP's highest priority objectives. Other objectives include:

- Demonstration of the potential of on-demand computing to support operational hurricane forecast operations at NHC.
- Inform future research and development needs as relating to established HFIP goals and objectives toward the development and implementation of the next-generation hurricane forecast system.

HRD, with a HFIP high-resolution test team from Texas A&M University and GSD with support from the NOAA OCIO and NCEP are:

- Porting and establishing baseline performance for a version of the Advance Research WRF (ARW) and the GSD Finite-Volume Icosahedral Model (FIM) to the TACC;
- Demonstrating the capability to ingest operational data in real or near-real time;
- Developing global and regional model products for this season and delivering these products to NHC for evaluation; and
- Setting-up, running, and evaluating global and regional model ensembles (at 15-km horizontal resolution global and 4.5/1.5-km km horizontal resolution regional) for track and intensity on several cases from the high-resolution model test plan. Inform future ensemble research needs.

## NUMERICAL ANALYSIS AND PREDICTION MODELING

The ESRL GSD continues to perform research and development on a high-frequency updated model/assimilation system within NOAA's operational atmospheric models, currently occupied by the Rapid Update Cycle (RUC). The RUC is heavily used by users especially within the aviation/transportation and severe weather forecaster communities, but also for public forecasts, marine, energy, and other applications. The initial version of the RUC was transitioned by GSD (its predecessor organization – PROFS) to NCEP (then, NMC) in 1994. Yearly upgrades have been made since then, of major proportion in 1998, 2002, 2005, and 2008.

GSD also has conducted forecast impact assessments with new observation types to consider potential operational use at NCEP including wind profilers, GPS-Meteorology precipitable water, TAM-DAR data, and METAR ceiling/visibility, and radar reflectivity, all resulting in operational implementations. The model updates every hour, incorporating information from virtually all high frequency data sources: hourly wind profiles; WSR-88D (Doppler radar) radar reflectivity, 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.

Along with NCAR, NCEP, and the university community, GSD has collaborated heavily on the development of the WRF model. The WRF model has 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. GSD and NCEP are scheduled to replace the RUC with the WRF Rapid Refresh model in 2010, updated hourly and extended to Alaska, Puerto Rico, and the Caribbean Sea.

GSD has also developed a unique hourly-updated, radar-initialized, storm-resolving (3-km) model forecast capability, the High-Resolution Rapid Refresh (HRRR). The HRRR real-time forecasts have demonstrated utility of 3km for aviation and severe weather forecast users, and a likely key role for NOAA's Warn-On Forecast capability. GSD's effective method for radar reflectivity and lightning assimilation will also be applied to tropical storm forecasts within the hourly updated Rapid Refresh model using proxy reflectivity data from satellite based estimates or aircraft-measured reflectivity. GSD has demonstrated this in the hourly updated 13km RUC and the 3-km High-Resolution Rapid Refresh. The goal here will be to improve high-frequency updating of short-range NWP forecasts.

GSD has developed a fire weather forecast system running at 0.5 km to predict environmental winds in and around active fires. Coupled to this are USFS fire behavior models to better predict the movement and evolution of fire lines. This model can be nested in large scale models like the HRRR above. GSD has developed storm resolving initialization methods (hot start) for individual storm prediction for warn-on-forecast applications. This would include heavy rain forecasts for flash flood warnings.

GSD has also led the development of WRF-Chem, a significant extension of the WRF model with a fully coupled chemistry with atmospheric physics. WRF-Chem is now used widely for air quality and other air chemistry research and various real-time demonstrations.

GSD has also pioneered the application of high resolution (3 km) ensembles for probabilistic quantitative precipitation forecasts aimed at hydrological prediction. The HMT effort previously described as been the catalyst for this effort. Work has focused on optimizing the ensemble by evaluating individual members, and debiasing precipitation forecasts and forecast probabilities.

GSD scientists lead work with other scientists from NOAA/ESRL toward development of a new global model including use of the adaptive isentropic-sigma hybrid vertical coordinate successful with the RUC model, accurate finite-volume horizontal advection, and use of an icosahedral horizontal grid. ESRL is collaborating with NCEP/EMC and GFDL on development of the FIM model (Flow-following Finite-volume Icosahedral Model).

Mesoscale dynamics research at GFDL in Princeton, New Jersey, 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. Current research focuses on extending these activities to the global domain through state-of-the-art global atmospheric models. High resolution mesoscale and regional models provide a key scientific tool to explore, verify, and validate parameterizations of unresolved processes such as convective and stratiform precipitation in the global models.

As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved numerical weather prediction models. Three groups at GFDL are engaged in weather research activities: Climate Dynamics and Prediction, Weather and Atmospheric Dynamics, and Atmospheric Physics and Chemistry.

The Goal of the Climate Dynamics and Prediction Group is to develop and use computer models of the atmosphere-ocean-ice-land system in order to:

- Identify and elucidate the physical and dynamical mechanisms which maintain climate and cause its variations on seasonal to centennial time scales
- Assess and understand the predictability of the climate system on seasonal and longer time scales, including the El Niño phenomenon
- Evaluate the impact of human activity on the Earth's climate system

This group is charged with studying and modeling climate phenomena on seasonal to multi-century time scales. The group's work is highly relevant to key elements of the NOAA Strategic Vision, especially Mission Goal 2 to "Understand climate variability and change to enhance society's ability to respond". In addition to examining a wide range of climate time scales, various members of the group have expertise spanning the expansive set of complex and interconnected parts that together constitute the Earth's physical climate system (this includes the atmosphere, ocean, land surface and sea ice). Group members participate in the development, testing, application, and analysis of numerical models of the climate system. Running on supercomputers, these models are the research tools used by group members to both advance our understanding of the Earth's climate system and to generate products relevant to assessment and policy decision support.

The Weather and Atmospheric Dynamics Group at GFDL improves our understanding of atmospheric circulations ranging in scale from hurricanes to extratropical storms and the general circulation, with an emphasis on extreme weather events and the interplay between weather phenomena and climate variability and change, using high resolution atmospheric modeling as the central tool (see figure). This effort is augmented by the Atmospheric Physics and Chemistry group, which performs research to improve our understanding of the interactive three-dimensional radiative-dynamical-chemical-hydrological structure of the climate system from the surface and troposphere to the upper stratosphere and mesosphere on various time and space scales. This is achieved by employing meteorological observations in conjunction with models for diagnostic analyses of atmospheric processes, and evaluating and improving parameterizations employed in weather and climate models; modeling the interactions between clouds, convection, radiation and large-scale dynamics to understand their roles in climate and climate change; and modeling the physics, chemistry and transport of atmospheric trace gases and aerosols to investigate the impact of future emissions on regional and global air quality, and to investigate the regional and global climatic effects due to changes in natural and anthropogenic radiatively-active species.

Together, these groups use the models to address problems of critical interest to the Nation. For example, there is now a very high degree of confidence that anthropogenic effects have already altered the climate system and that this forcing will increase in the coming decades. Insurers are raising underwriting standards and rates in hurricane-affected markets, and some insurers are withdrawing from some markets. Nonetheless, infrastructure is still being built or rebuilt in areas vulnerable to sea level rise and hurricanes. At the same time, sea level rise seems to be accelerating and hurricane activity is relatively high. Water resource management, urban planning, and agricultural decisions are being made even as observations and models suggest the potential for persistently drier conditions. The trend towards an ice-free Arctic has major social, economic, and policy implications, as well as the potential to accelerate global warming. Energy technologies that might affect global change need to be examined. The Nation must plan for the geopolitical challenges of global warming, because many of its most severe effects are expected in regions where fragile governments are least capable of responding to them.

To prepare for and confront these effects, an understanding of the regional impacts, the role of extreme events and abrupt change, and their interactions with natural variability are being developed so that decisions can be made with the best possible scientific information. Over the last half century in general and the last few years in particular, NOAA's Geophysical Fluid Dynamics Laboratory has demonstrated world leadership in pushing the boundaries of climate prediction. Through direct participation in producing the Intergovernmental Panel on Climate Change 2007 Assessment and the Administration's Climate Change Science Program Synthesis and Assessment Reports, GFDL's premier climate science capacity and recent investment in computer model infrastructure allow NOAA deliver essential climate forecast information at the regional and local level and provide an invaluable and unique opportunity for the Nation to make critical progress in global change science.

ARL 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 continues to work closely with the Chemical Sciences Division (CSD) of ESRL to maintain the nation's surface radiation network (SURFRAD), data from which are now routinely employed to test both forecast mesoscale models (such as the Eta model) 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 volcanoes, industrial enterprises, and nuclear accidents. In recent work, ARL is adapting a new system developed to forecast dispersion of smoke from forest fires, in a study performed in collaboration with the Association of South East Asian Nations, the U.S. Forest Service, and The Mediterranean Centre for Environmental Studies Foundation. The present program will provide interim products to the joint NOAA-EPA Air Quality Forecasting Program to improve smoke dispersion estimates in the particulate forecast model.

## AIR QUALITY RESEARCH

The principal mission of 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 the Environmental Protection Agency, Department of Energy and Department of Defense.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction to support operational predictions and emergency response. The division is researching mercury fate and transport through measurement and modeling studies.

The ARL 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. Recent efforts have focused on the air-surface exchange of mercury in polar and coastal environments and of nitrogen (both oxidized and reduced) over agricultural soils.

The ARL Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales. The ARL Special Operations and Research Division (SORD) in Las Vegas, Nevada conducts research

Figure 3-DOC-7. A 42-hour forecast on September 4, 2008 of column-integrated total condensates (cloud water, rain water, snow, cloud ice, and graupel) using a prototype global atmospheric model to be used for future studies of climate change.

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. ARL participates in 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-developed 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. ISIS and SURFRAD are presently operated by Global Monitoring Division (GMD) of ESRL. This work forms an intersection with the new flux measurement networks in the United States and overseas, referred to as "Ameriflux" and "Fluxnet."

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 an air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. ARL also provides forecast support to NOAA's emergency response systems with emphasis on chemical, nuclear, and volcanic events. For this application, ARL develops and couples advanced dispersion models with the forecast products of the NWS to provide a basis for trajectory and dispersion calculations. The models in question are now widely accepted. The Hazardous Atmospheric Release Model (HARM) is operationally employed at a number of DOE locations. The ARL Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model is now operational in many countries, including China and Australia, as the national dispersion forecasting capability. It also serves the NWS in this role. Registered users can also access HYSPLIT products via the Internet. HYSPLIT is the major product employed in the operations of the Regional Specialized Meteorology Center (RSMC) set up as a joint undertaking of ARL and NCEP under the auspices of the World Meteorological Organization (WMO). The WMO/ RSMC is the source of dispersion products in the event that a pollution plume (in this case, radioactive) crosses international boundaries.

The provision of dispersion forecasts by ARL scientists extends to two specific areas of special relevance - the Nevada Test Site and the Idaho National Laboratory. ARL maintains staffs of dedicated dispersion meteorologists at each location, where site-specific models are developed and run using data generated by dedicated regional networks of meteorological sensors. These sites also serve as research testbeds for improving ARL's dispersion models, such as the HYSPLIT model.

The Chemical Sciences Division (CSD) of ESRL coordinates the Health of the Atmosphere air quality research effort. 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. CSD, ARL, GMD, GSD, PMEL, and PSD participate in the research. In summer of 2006 a, major field study was carried out to characterize air quality in New East Texas. Ground-based measurements, ship and aircraft measurements, forecasting, and modeling analyses were applied in the research. Among the processes investigated were the role of nighttime chemistry in the formation of ozone and PM pollution, the role of the sea-breeze/land-breeze circuit in influencing Houston's air quality, and the role of the marine boundary layer as a conduit for the movement of pollutants throughout the region. The Health of the Atmosphere research goals are:

- Characterize regional ozone and particulate matter (PM) episodes
- Characterize the factors that cause poor air quality in regions of the United States where excessive levels of ground-level ozone and fine particle

pollution are occurring.

- Document trends in air quality: Help evaluate predicted atmospheric responses to changes in emissions (i.e., the ongoing measurements provided by the Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMoN) and the ozone profiling networks).
- Develop a better understanding of the fundamental science underlying the processes responsible for the formation and distribution of fine particles in the atmosphere to improve the atmospheric predictive capability that links sources of fine particles and their precursors to human exposure and visibility impairment.

Under the future Health of the Atmosphere research umbrella, the OAR Laboratories integrate their meteorological, chemical, and forecasting expertise to support 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, the variation in those levels is also influenced by meteorology, both in the short term and longer term. Therefore, assessing both the intended long-term improvements in air quality and the more-episodic variations requires an understanding of pollutant transport, transformation, and loss. 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.

CSD and GMD, working with collaborators throughout North America and Europe, are using ozonesonde releases to characterize the vertical distribution of ozone over North America. Coordinated ozonesonde releases have been conducted in conjunction with field intensives in New England (2004) and Texas (2006). The data collected has provided new insights into the import of ozone from Asia, transport aloft and the role of lightning in ozone formation in the upper free troposphere.

CSD conducts laboratory studies of the chemical processes that are responsible for ozone and fine particle formation and transformation in the atmosphere. These studies are designed to elucidate the chemical mechanisms and quantify the kinetic and thermodynamic parameters needed to properly represent these processes in predictive models.

CSD develops and deploys lidars that are capable of characterizing the vertical structure of ozone and aerosols in the atmosphere. These instruments are deployed on NOAA research aircraft, ships, and at surface sites to characterize the regional distribution of ozone and PM in three dimensions. The data collected provides detailed information on the regional and inter-regional horizontal transport and vertical mixing of ozone and PM pollution.

CSD develops fast response instrumentation for use on mobile platforms (ships and airplanes) that are capable of characterizing the atmospheric pollutant mix. These instruments are designed to characterize the chemical composition of the atmosphere, as well as the optical (scattering and absorption) and physical (e.g. size distribution) properties of ambient PM.

PSD and CSD use their 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. These instruments are deployed at surface sites and on NOAA research ships during the regional air quality intensives such as the Texas air quality study.

CSD works with GSD and PSD to develop and evaluate air quality models. These models are used to aid in the interpretation of data collected during regional field studies and to produce prototype air quality forecasts. The detailed physical and chemical data collected during intensive field studies are used to diagnostically evaluate these models and their components.

The Air Quality Research Subcommittee (AQRS) of the Committee on Environment and Natural Resources (CENR) provides interagency collaboration at the U.S. federal level. NOAA co-leads the AQRS. 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.

EARTH SYSTEM SCIENCE EDUCATION AND OUTREACH

Science On a Sphere® is a unique visualization technology that was invented by Dr. Sandy MacDonald, Director of the Earth System Research Laboratory (ESRL) in Boulder, CO. In August of 2005, NOAA received a patent for Science On a Sphere®. Using computers coupled with video projectors, the system presents NOAA's global science in an engaging three-dimensional representation of the Earth's features as if they were viewed from space. By September 2008, there will be 25 installations of NOAA Science On a Sphere in science and technology museums and centers, research laboratories, aquariums, and technology visitor centers in the United States and overseas, including the Smithsonian's new Oceans Hall, Another 6 museum installations are expected to be funded in FY09 through the NOAA Office of Education competitive grants program.

Science On a Sphere® maps directly to NOAA's mission goal to "Serve Society's Needs for Weather and Water Information" and its performance objective of enhancing environmental literacy and improving understanding, value, and use of weather and water information and services. This innovative technology is intended to educate multi-generational and now international audiences about ongoing NOAA research being conducted at many laboratories and to inspire students so that they might investigate scientific career paths. Over a half dozen international installations are planned for Europe, Asia, and possibly Australia. It is estimated that over 15 million people will be seeing SOS in FY09 worldwide.

ESRL is also developing a NOAA virtual world in the rapidly growing online world of Second Life and others as they are introduced via the web. Users can learn about NOAA's leading edge science and have experiences in the virtual world they cannot have in the physical world such as soaring through a hurricane on the wing of a hurricane hunter aircraft. The web site offers another way to attract the next generation of Earth system scientists. As the technology becomes more sophisticated, scientists may also use the site to collaborate on research, hold virtual meetings and give public presentations.

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 en-vironment for present and future generations. NOS is the primary civil agency within the federal govern-ment responsible for the health and safety of our nation's coastal and oceanic environment. Largely through the Tides and Current Program line, NOS acquires water levels, currents, winds, and other physi-cal oceanographic and meteorological data, and distributes these data and circulation predictions as ele-ments 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 transporta-tion, including the transport of oil and other hazardous materials. NOS also provides coastal oceanographic and meteorological products required by the National Weather Service (NWS) to meet its short-term weather and forecasting responsibilities, including tsunami warnings and storm surge forecasts. NOS manages several observing systems and programs, however four in particular are heavily linked to the capability of NOAA to meet weather and water needs of the nation.

National Water Level Observation Network (NWLON).

NOS manages the NWLON, which officially consists of 200 stations (4 additional stations will be-come part of the network by the end of FY09) 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 Nautical Charting Program, NWS Tsunami Warning System, NWS storm surge forecast activities, and the Climate and Global Change Program. A DCP NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS a 6-minute intervals and imbedded in those data streams are high-rate one-minute averages for tsunami use. The 6-minute interval GOES transmission capability also supports the NWS storm surge forecast when expected elevations are predicted or observed during coastal storms and hurricanes. This capability for high–rate data has recently been implemented at almost all NWLON by the introduction of 6-minute interval GOES transmissions. Although not all NWLON stations are presently equipped with meteorological sensors, an increasing number of stations are each year. Water level and meteorological data are automatically formatted into bulletin format for inclusion into the NOAA AWIPS pipeline.

**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 measurement and integration of real-time environmental observations, forecasts, and other geospatial information (Figure 3-DOC-7). PORTS® measures the coastal environment and disseminates observations and predictions of water levels, currents, salinity, bridge air gap and many meteorological parameters, e.g. winds, air temperature and barometric pressure, needed and requested by the mariner to navigate safely.

The 18 existing PORTS® systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. PORTS® are partnership programs in which local operating partners fund the installation and operation of the measurement systems. The largest of NOS' existing installations is composed of over 100 separate instruments. The smallest consists of a single water level gauge and associated oceanographic and meteorological instruments, i.e. winds, barometric pressure, etc. Regardless of its size, each PORTS® installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting U.S. 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 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 the information necessary to mitigate the damages from a spill, should one occur. An exten-sible PORTS® can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS).

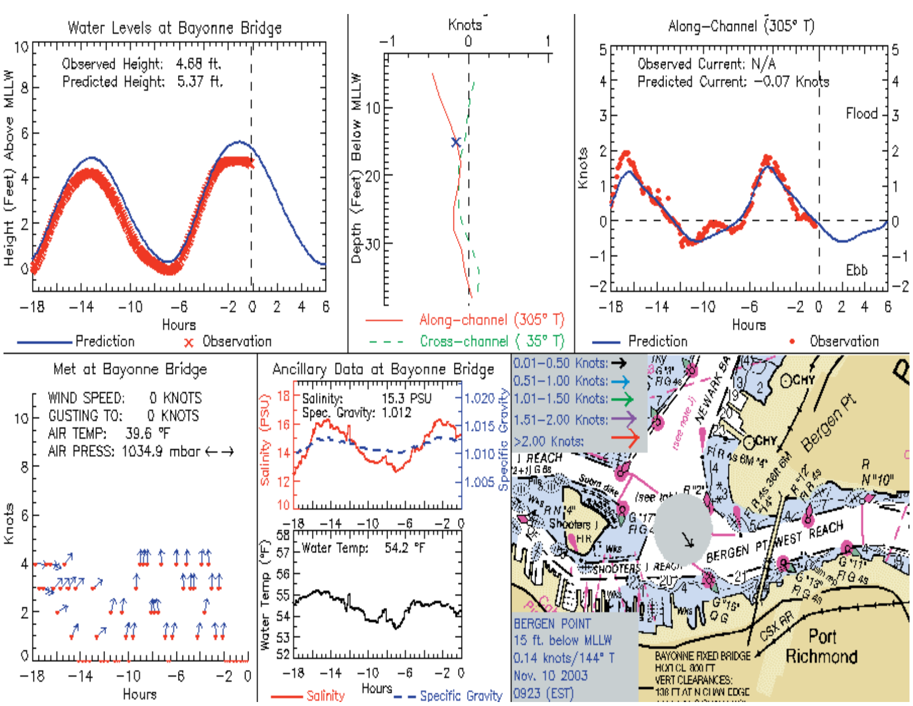
National Operational Coastal Modeling Program (NOCMP).

NOCMP serves a variety of users with oceanographic nowcast forecast products for ports, estuaries and the Great lakes. 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. The New York/New Jersey Harbor nowcast/forecast model came on line in 2003, followed by a Houston/Galveston Bay nowcast/forecast model in 2004. Newer models include the St. Johns River, FL and the Great Lakes. In cooperation with OAR and NWWS, the NOS CO-OPS now runs 5 models as part of the Great Lakes Operational Forecast System (GLOFS) providing forecast guidance for water level, wind, currents and water temperature. Also, ongoing research will enable PORTS® or similar systems to incorporate biological and chemical sensor systems and forecast models as required and integrate the information with circulation measurements to provide information on transports of mate-rials in the ecosystem essential for effective marine resource management and homeland security.

## THE NOS CONTINUOUS REAL-TIME MONITORING SYSTEM (CORMS)

CORMS was designed to operate on a 24hour/7 days a week basis to ensure the accuracy and working status of tide and current observations acquired via the NWLON and 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 and systems, including the operational nowcast/forecast models, determines data quality, and identifies and communicates the presence of invalid or suspect data to real-time users/customers who rely on the data. CORMS is especially vigilant during storm and tsunami events to ensure the full set of products and services is being disseminated in a timely fashion. An advanced version of this system, CORMS AI, is presently in developmental stages.

Figure 3-DOC-8. New York/New Jersey PORTS: Bergen Point Composite



The NOAA Office of Marine and Aviation Operations (OMAO) operates a fleet of survey ships and aircraft to support NOAA mission goals. NOAA's ship fleet includes oceanographic and atmospheric re-search vessels. The NOAA aircraft fleet includes aircraft that collect environmental and geographic data essential to NOAA hurricane and other severe weather and atmospheric research; and aircraft that con-duct aerial surveys for hydrologic research for forecasting flooding potential from snow melt.

## NOAA SHIPS SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA Ship RONALD H. BROWN, an oceanographic and atmospheric research platform, is the largest vessel in the NOAA fleet (274 feet). With its instruments and sensors, the BROWN sails worldwide supporting scientific studies to increase our understanding of the world's oceans and climate. The BROWN also carries a Doppler radar system to support at-sea meteorological observations.

NOAA Ship KA'IMIMOANA primarily supports the research programs of NOAA's Tropical Atmos-phere-Ocean (TAO) Project (real-time data from moored ocean buoys for improved detection, understand-ing and prediction of El Niño and La Niña). These research programs are designed to improve our understanding of the role of the tropical ocean in the world's climate. The ship deploys, recovers, and services deep sea moorings that measure ocean currents, ocean temperatures, and atmospheric variables, throughout the equatorial Pacific Ocean. In addition to data from these moorings, the ship measures upper ocean currents, surface salinity, and carbon dioxide content.

RONALD H. BROWN and KA'IMIMOANA annually support the Tropical Atmospheric Ocean (TAO) Array by servicing approximately 60 ATLAS and current meter moorings in the central and eastern equatorial Pacific. In FY2009, the RONALD H. BROWN will work in cooperation with the Woods Hole Oceanographic Institute to conduct mooring recovery and deployment operations of the Stratus Ocean Reference Station (the ninth setting) under the stratocumulus clouds off Chile and Peru. The ship will conduct meteorological and air-sea flux observations to document and establish the accuracy of the moored metrological observations, and to observe the oceanic and atmospheric variability. This region is of critical importance to climate predictability. Additionally, after the Stratus project the BROWN will sup-port VOCALS-REx (**V**AMOS **O**cean-**C**loud-**A**tmosphere-**L**and **S**tudy – **R**egional **Ex**periment) off the coast of Chile. VOCALS-REx will focus on interactions between clouds, aerosols, marine boundary layer proc-esses, upper ocean dynamics and thermodynamics, coastal currents and upwelling, large-scale subsidence, and regional diurnal circulations, to the west of the Andes mountain range. The field experiment is ultimately driven by a need for improved model simulations of the coupled climate system in both the Southeast Pacific and over the wider tropics and subtropics

RONALD H. BROWN will also conduct the Northwest Tropical Atlantic Station (NTAS) project, which investigates surface meteorological forcing and oceanographic response in a region of the tropical Atlantic with strong sea surface temperature anomalies on decadal time. These issues are addressed through the analysis of surface mooring observations from a site near 15° N, 51° W. Following the NTAS project, BROWN will conduct the Pirata Northeast Extension (PNE) study to improve understanding of the West African monsoon and its influence both on the regional environment as well as its role in Atlantic Tropical cyclone development. OMAO vessels also support the NOAA National Data Buoy Center (NDBC) in recovery of buoys which have been disabled or gone adrift.

## NOAA AIRCRAFT SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA aircraft support a broad range of meteorological activities and projects with its fleet of air-craft based at MacDill Air Force Base in Tampa, Florida. Three of its twelve aircraft are dedicated to this purpose throughout the year, providing valuable information to NOAA and the nation.

Operations of the NOAA G-IV and WP-3D aircraft during the hurricane season of 2007 were very similar to the 2006 season with an exception being that the G-IV flew about half the number of hours in 2007 while the P-3s almost double their output over the previous year. All told, these three aircraft flew a total of 45 missions and 273 hours in the relatively quiet season.

The NOAA Gulfstream, G-IV (SP) (N49RF), provides scientists with a platform for the investigation of processes in the upper troposphere and lower stratosphere. With an operating ceiling of 45,000 ft, the G-IV is a critical tool for obtaining the data necessary to improve hurricane and winter storm track fore-casts and for research leading to improvements in hurricane intensity forecasts. The G-IV is also being used for air chemistry studies where a high altitude capability is required.

The NOAA G-IV annually supports Hurricane Synoptic Surveillance missions where the aircraft flies in the environment surrounding the storm at a high altitude releasing GPS dropsondes at pre-selected locations. The data from these vertical atmospheric soundings are transmitted from the aircraft to the NCEP computer site where they are incorporated into the hurricane computer models to improve hurricane track forecasts. The dropsonde directly measures temperature, pressure, and humidity as it falls through the atmosphere to the surface, and computes wind speed and wind direction using a full-up GPS receiver. Recent estimates of the improvement in hurricane track predictions utilizing this aircraft and dropsonde are between 20 and 30 percent, resulting in a savings of $10 million or more per hurricane in warning and preparedness costs. Because of the relatively slow hurricane season in 2007, with few storms threatening the United States, the use of the NOAA G-IV for hurricane surveillance was limited to only eight flights totaling 65 hours.

The NOAA G-IV also annually supports the Winter Storms Reconnaissance Program in an effort to improve forecasts released 24 to 96 hours before winter storms in the United States. This aircraft, in con-junction with the Air Force Reserve's WC-130s, utilize the GPS dropsondes to collect data on developing severe winter storms over the Pacific Ocean that will seriously impact the continental U.S. and Alaska. During one month of the two-month season, both aircraft operate in tandem, one from Alaska and the other from Hawaii, to collect data both north and south of the jet stream simultaneously. General improvement in forecast accuracy of up to 20 percent has already been seen, and even higher percentage improvements on individually targeted events have been realized from this program. Typically, during the final month of the program, the NOAA G-IV operates alone from either a base in Alaska or Hawaii as the case may dictate. Use of the G-IV for the 2007 Winter Storms Reconnaissance program was significantly higher than for the Hurricane program. Operating solely from a base in Hawaii, this aircraft flew 24 missions for 160 hours during January and February.

A recently added mission for the G-IV, supporting the Hurricane Research Division's Saharan Air Layer Experiment (SALEX), is still ongoing each hurricane season, subject to the availability of atmospheric conditions and flight hours. The outbreaks of dry Saharan dust have been shown to have a dampening effect on the development of tropical cyclones in the Atlantic, and the G-IV, with its high altitude and dropsonde capabilities, is the ideal tool to study this phenomenon. Typically the aircraft will operate from a forward base in Barbados, as it is the most eastern island in the western Atlantic Ocean.

NOAA's Chemical Science Division (CSD) of the Earth System Research Laboratory, located in Boulder, CO, is continuing to use the G-IV for some of high altitude air quality studies. CSD in past years has used instrumentation to measure ozone, CO and VOCs (volatile organic compounds). The Division has reaped a harvest of quality data piggy-backing on WSR missions and scientists from this organization have either published or presented a significant number of publications over the past few years utilizing the data obtained on the G-IV.

NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations, is supported by two WP-3D Lockheed Orion aircraft (N42RF and N43RF) which carry a full array of state-of-the-art environmental research instrumentation. The aircraft research and navigation systems provide de-tailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. NOAA's Aircraft Operations Center (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.

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also pro-vided storm data to the National Hurricane Center (NHC) in real-time, transmitting flight level data, GPS dropsonde messages, as well as radar images transmitted via its multiple aircraft-satellite data links. With the Stepped Frequency Microwave Radiometers (SFMR) now operational, increasing emphasis was placed on utilizing the NOAAWP-3D to map the surface wind fields in and around hurricanes and tropical storms in 2007. Real-time surface wind speed maps are critical to providing more accurate forecasts of the extent of hurricane and storm force winds. The AOC aircraft also augment the Air Force Reserve reconnaissance aircraft during particularly active storm periods when tasking requirements exceed their available resources.

Each year, one of the NOAA WP-3Ds participates in a Hurricane Awareness Tour targeting, alternately, the Gulf and East coast regions of the U.S., those areas that are most vulnerable to landfalling storms. This educational outreach effort is directed at both middle-grade school children, the age group most likely to see, learn and convey a message home, as well as the general public. These tours are op-erated in concert with the participation of officials from NHC, the Red Cross, FEMA and other local and state emergency management personnel. This is becoming an increasingly more popular and successful venture as coastal populations grow and the threat of an increasing number of storms place more people in harm's way.

During 2007, the two NOAA WP-3Ds supported several major research experiments in support of NOAA's Hurricane Research Division. During this past season these aircraft embarked on a new en-deavor, to obtain 3-dimensional horizontal wind fields in developing tropical systems and hurricanes utilizing their tail Doppler radars (TDR). This effort is part of a new initiative to obtain data that can be assimilated into the HWRF hurricane forecast model for the purpose of improving intensity forecasts. As this was a new effort, much of the 2007 flight program was spent developing the techniques and flight proce-dures to obtain the optimum set of data for ingestion into the models. Operating from bases in St. Croix, VI and Barbados, the P-3s flew numerous missions on a round-the-clock basis into Tropical Storms, Erin, Ingrid and Karen as well as Hurricane Felix and Tropical Depression #10. One of the P-3s also partici-pated in a joint UAS (Aerosonde) – aircraft mission into TS Noel in early November. Both of these ex-periments have continued through the 2008 season and will reoccur in 2009.

The NOAA WP-3Ds annually support both a summer and winter operation of a NESDIS satellite validation program. Operating in regions of high winds and heavy precipitation, one of the WP-3Ds, equipped with microwave scatterometers and radiometers, provide under-flight validation of NOAA QuickScat and WindSat sensed ocean surface wind vectors. Traditional venues for these operations are Alaska or Newfoundland in the winter and the Atlantic and Caribbean regions during the summer hurricane season.

A NOAA AC-695A Commander 1000 (N45RF) and a NOAA AC-500 Shrike (N51RF) are used annually to conduct important snow pack surveys in the northern and western continental U.S., Alaska, and southern Canada. During these survey flights, the gamma radiation sensors aboard these aircraft measure the naturally occurring terrestrial radiation emitted from the ground to obtain snow water–equivalent estimates. This data is transmitted to the National Operational Hydrologic Remote Sensing Center (NOHRSC) up to three times a day from each aircraft, and after further processing the data is dis-tributed to NWS field offices within five minutes of receipt from each aircraft. These data are used by the NWS to forecast river levels and potential flood events resulting from snowmelt water runoff. Hydroelectric power interests and other water supply managers also use the data to regulate water storage and delivery.

In 2007 the Tunable Optical Profiler for Aerosol and Ozone (TOPAZ) LIDAR system was tested on a NOAA DeHavilland Twin Otter (DHC-6) aircraft for remote sensing of local and regional ozone and aerosol distribution. Airborne remote sensing enables tracking of plumes from urban areas and point sources, identification of isolated regions and layers of high ozone concentration, observations of atmospheric layering as characterized by aerosol structure, and investigation of local meteorological effects such as sea breezes and urban heat islands on pollution transport and mixing. This system was again used effectively during the 2008 field campaign along the Colorado Front Range and will reoccur in 2009.

Inclusion of a remote sensing aircraft also provided information on the three-dimensional resen-tativeness of in situ observations made on the NOAA WP-3D and other aircraft during those periods when the flight tracks of the two aircraft sample the same region.

# DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates military environmental services to provide specialized worldwide meteorological, space environmental and oceanographic analysis, and prediction services in support of military forces and joint operations. Military environmental services directly support all phases of military operations from strategic planning to tactical operations. While the Army and Marine Corps each have small weather operations capabilities, the Navy and Air Force are the primary sources of military weather products and services. 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 Program to meet unique military requirements. Observational data are sent through military communications systems to military and civil facilities in the United States and overseas.

## UNITED STATES AIR FORCE

### METEOROLOGICAL AND SPACE ENVIRONMENTAL SERVICES

Air Force weather forces provide high-quality, mission-tailored terrestrial and space environment observations, forecasts, and services to the U.S. Air Force (USAF), U.S. Army (USA), and a variety of U.S. Government (USG) departments and agencies. AF weather is in the process of transforming their support to the USA by integrating forecasting tools into Distributed Common Ground System-Army, developing an Army weather concept of operations, and increasing sensing capability in Operation IRAQI FREEDOM (OIF) and Operation ENDURING FREEDOM (OEF). See Section 3, U.S. Army, for details of Air Force weather support to the Army.

AF WEATHER ORGANIZATION

AF weather is functionally organized under the Director of Weather (AF/A3O-W), Directorate of Operations (AF/A3O), Deputy Chief of Staff, Operations, Plans, and Requirements (AF/A3/A5), Headquarters Air Force. The Director of Weather oversees Air Force-wide training, organizing, and equipping of AF weather organizations to include the following functions:

- Development of doctrine, policies, requirements, and standards for weather support
- Evaluation of weather support effectiveness
- Management of weather officer, enlisted, and civilian career fields
- Development and implementation of mid- to long-range plans for the organization, equipment, manpower, and technology necessary to meet future Air Force and Army weather requirements
- Advising Air Staff and subordinate headquarters weather functional managers regarding manpower, career field management, personnel utilization, training, operations policy and procedures, and technology acquisition
- Advocating and fielding standardized weather equipment

AF weather operations provide a Total Force capability employing over 4,100 Active Duty (AD) and Reserve Component (RC) military and civilian personnel supporting Air Force and Army conventional and Special Operations Forces (SOF) worldwide. The majority of AF weather personnel are focused on two distinct, yet related functions: characterizing the past, current, and future state of the natural environment, and exploiting environmental information to provide actionable environmental impacts information directly to decision-makers.

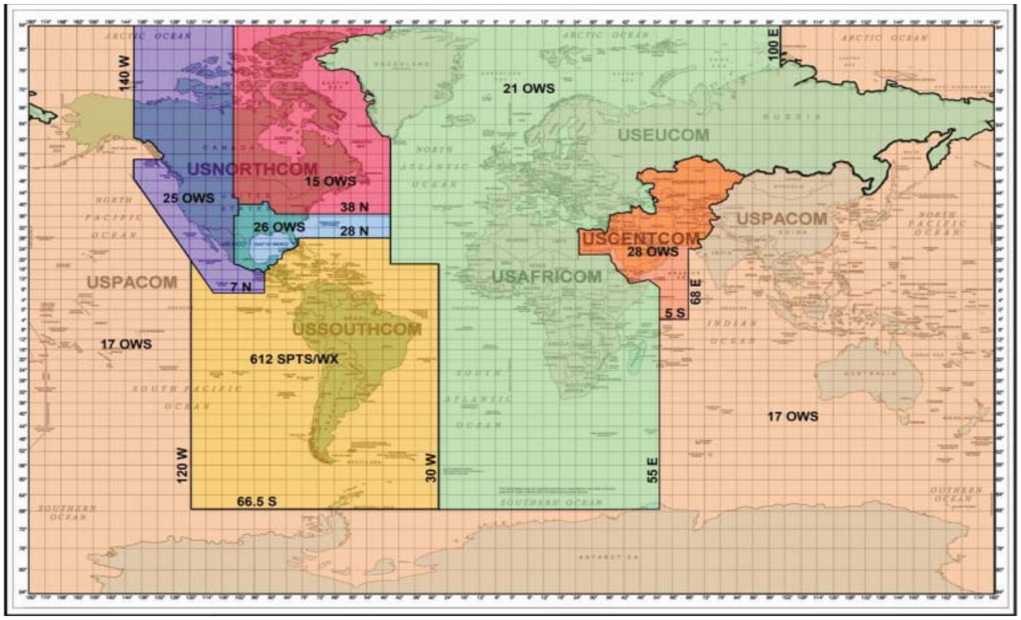
AF weather is organized in a 3-tier structure to maximize capabilities that can be accomplished in the rear area via reach back technology. This minimizes forward presence on the battlefield, making a "light and lean" presence consistent with the overall USAF vision for contingency operations in the 21st century. For the first time, AF weather is pursuing formalized Tactics, Techniques, and Procedures (TTPs). TTPs are commonplace throughout the AF, and developing these standardized tools will help AF weather deliver timely, accurate, relevant, and consistent products and support when and where needed. AF weather is working with the AF Manpower Agency to complete and implement capabilities-based man-power standards and documenting missions and units supported which will further ensure the AF has weather personnel at the right place at the right time. Another initiative underway is in the area of metrics. The goal is to provide verification information on systems, weather warnings, terminal forecasts, mission execution forecasts, and model performance, that will assist AF weather leadership and the AF to make informed decisions concerning the Air Force Weather Weapon System (AFWWS), including the equipment, software, and various tools necessary to deliver the five core processes of collection, analysis, prediction, tailoring, and integration. Environmental characterization is typically accomplished in large, centralized units focused primarily on global and regional scales of weather, whereas support to decision-makers is primarily the realm of personnel embedded in operational units. Normally, these personnel are assigned to weather flights under the operations support squadron of a flying wing, a weather squadron collocated with a supported Army unit, or a weather squadron providing a unique capability such as space launch support. These weather squadrons may include geographically separated detachments and operating locations.

The centerpiece of global-scale collection and production is the Air Force Weather Agency (AFWA), Offutt AFB, NE, a field operating agency reporting directly to the Air Force Director of Weather. AFWA provides timely, accurate, relevant, and consistent terrestrial and space weather products necessary to effectively plan and conduct military operations at all levels of war. AFWA operates a satellite data processing center and a centralized climatology center with the largest military archive of meteorological data in the world. The agency runs numerical weather prediction models, conducts global cloud and snow analysis, and runs cloud models. AFWA also maintains a global database, and provides dedicated support to SOF and the Intelligence Community (IC). The agency consists of a functional management headquarters; the 1st Weather Group (1 WXG) with three subordinate CONUS operational weather squadrons (OWS); the 2nd Weather Group (2 WXG), which operates three squadrons, two at Offutt and one at Asheville, NC, as well as five detachments and operating locations; and, the Air Force Combat Weather Center at Hurlburt Field, FL, which transitions technology to support tactical-level weather operations while developing operational concepts, tactics, techniques, and procedures.

The 1 WXG commands three operational weather squadrons performing CONUS missions: 15 OWS at Scott AFB, IL, 26 OWS at Barksdale AFB, LA, and 25 OWS at Davis-Monthan AFB, AZ. The 2 WXG, collocated with HQ AFWA at Offutt AFB, NE, consists of the 2nd System Operations Squadron (2 SOS) which provides automated weather characterization on a global scale, the 2nd Weather Squadron (2 WS) which provides global coverage of forecaster-in-the-loop products to exploit the weather as well a backup for four national weather centers (Space Weather Prediction Center, Washington-Volcanic Ash Advisory Center, Storm Prediction Center, and Aviation Weather Center), and the 14th Weather Squadron (14 WS) at Asheville, NC, which provides centralized climatological database services, produces specialized weather-impact information for the Department of Defense and allied nations, and warehouses and distributes atmospheric science-related technical information. Current plans are to transfer backup for the Storm Prediction Center and Aviation Weather Center from 2 WXG to 1 WXG.

Six operational weather squadrons form the backbone of regionally focused weather operations, providing a variety of weather forecast products and support to units assigned to and/or deployed into their Area of Responsibility (AOR). These AORs are depicted in Figure 3-DOD-1. OWSs produce and disseminate terminal aerodrome forecasts, weather watches, warnings, and advisories, planning and execution area forecasts, and other products using the OWS Production System Phase II (OPS II) until they receive the Joint Environmental Toolkit (JET). JET

Figure 3-DOD-1. Air Force Operational Weather Squadron (OWS) areas of responsibility (AORs) overlaid on geographic combatant commander AORs.




fielding began in summer 2008 and will be complete in the fall of 2009. OWSs also provide theater-scale, tailored environmental information to guide development of mission execution forecasts by AC and RC weather personnel embedded in operational units. Moreover, OWSs provide flight weather briefings to aircrews operating within their AOR without home station support or as requested by base or post-level weather forces.

At the base and post level, weather forces provide and disseminate observations and develop tailored mission execution forecasts based on centrally produced guidance. These personnel also act as "eyes forward" for their supporting OWS. Weather personnel supporting conventional AF operations typically deploy with a New Tactical Forecast System (N-TFS), which is being upgraded to the Joint Environmental Toolkit (JET) starting in mid 2008, the TMQ-53 tactical observing system for semi-permanent sites, and hand-held Kestrel observing kits. This equipment, coupled with robust communications to receive weather data including satellite imagery, provides the essential capability required for deployed weather forces to meet operational requirements.

The Reserve Component (RC) is composed of the Air Force Reserve Command (AFRC) and the Air National Guard (ANG). AF weather continues to integrate these forces to more closely align with Active Duty (AD) weather force operations. Air Force RC weather personnel augment the AD at all levels. In some cases, the RC provides very unique weather related services not duplicated in the AD force, such as AFRC's 53d Weather Reconnaissance Squadron (53 WRS) and the ANG's Weather Readiness Training Center (WRTC).

To augment OWS operations, AFRC organized two operational weather flights (OWF), each staffed by AFR weather personnel, capable of augmenting an OWS either in the CONUS or overseas. Additional AFR weather personnel serve as individual mobilization augmentees (IMAs) assigned to various active AF weather organizations at all echelons, typically in staff, forecasting, or scientific roles. There are also AFR weather personnel in Air Reserve Technician positions, i.e., combined full-time Civil Service/AFR military positions, employed by the 53d WRS as Airborne Weather Reconnaissance Officers. Lastly, AFRC contract weather personnel provide weather services at AFRC-operated bases in the CONUS.

The ANG traditional program consists of 27 numbered weather flights, ranging in size from 13 to 25 personnel, who meet monthly to train for their wartime mission. These flights provide weather support to ANG and Army National Guard units. ACC-gained ANG wings also have up to four traditional weather positions to provide weather operations for each wing's flying mission. In addition, there are traditional weather positions in two ANG Special Tactics Squadrons (AF Special Operations Command), and four ANG UAV units (Predator). The ANG also has 7 contract and 4 civil service locations where they are responsible for providing peacetime weather support to airfield operations. The WRTC at Camp Blanding, near Starke, FL, provides weather force operations training.

## CHARACTERIZE THE ENVIRONMENT

To characterize the environment across the globe, AF weather forces continually improve the core processes of collection, analysis, and prediction.

Collection

AF weather forces collect terrestrial and space environmental measurements from ground-, sea-, air-, and space-based sensors across the globe. While openly shared foreign data greatly improves the coverage of measurements across the globe, the Department of Defense retains an assured global weather collection capability. In regions where air, space, and land operations are occurring, environmental data may be insufficient; consequently, the AF maintains a capability to deploy and establish an in-theater environmental data collection network.

AF weather personnel provide observations essential for effective military operations. Weather personnel at both Air Force and Army locations (garrison and deployed) oversee automated observations and ensure they're available to local users and transmitted to a centralized database where they are assessable at military and civil locations throughout the world for subsequent weather analysis and forecasting. U.S. and foreign rawinsonde reports are primary sources of upper air observations. These observations are supplemented with military and civilian pilot reports. The Army's automated and limited observations and their artillery meteorology (ARTYMET) program augment Air Force observations in the tactical environment.

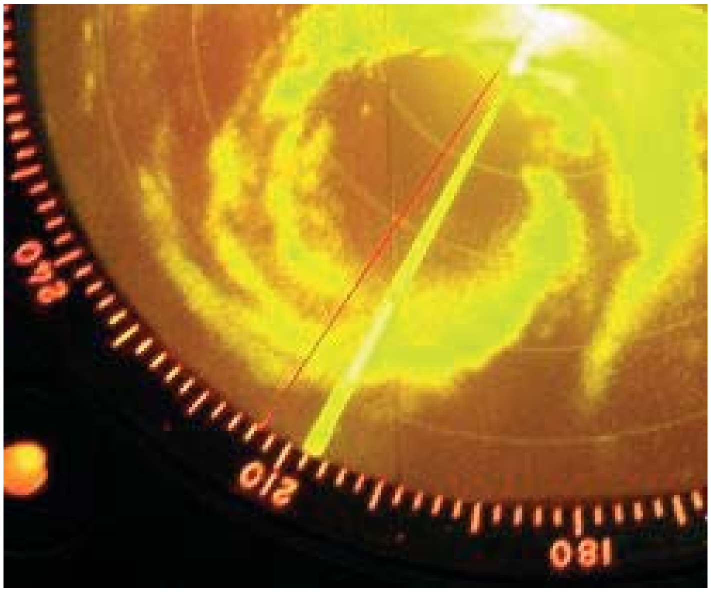
The Observing System 21st Century (OS-21) program is providing a much-needed, state-of-the-art life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. AF weather completed fielding 110 of the original automated fixed-base systems, AN/FMB-19, in FY 2007, and will continue fielding the follow-on fixed-base automated observing system, AN/FMB-22, with 30-40 systems to be initially installed through 2010. These automated systems are enabling AF weather personnel to devote more time to tailor and integrate weather into war fighter operations.

The AN/FMB-22 is intended to be installed at supplementary aerodromes such as heliports, training fields and testing areas, and certain other airfields. It has many of the same components as AF weather's deployable automated observing system (TM-53), hard-mounted on a pole mast for permanent installations. Government Developmental Test and Evaluation (GATE) will began during summer of 2008; upon completion of testing, AF weather anticipates to begin installations in early FY 2009.

AF weather is in the process of procuring "Weather Pod" observing systems that will be fielded as the remote expendable OS-21 configuration in support of AF and Army operations. They will be used to take observations at locations where AF weather personnel are deployed as well as at locations where there are typically no weather personnel, such as forward operating bases and forward air refueling ports. The Weather Pods may also be placed along select flight routes and other locations of particular weather interest. As a COTS system, the weather pods will undergo a limited operational utility evaluation (OUR) during summer 2008, with fielding anticipated to begin in either late FY 2008 or early FY 2009. Components of the weather pod system include a primary weather pod sensor that senses temperature, dewpoint, wind, and atmospheric pressure, a ceiling pod that senses cloud coverage up to 5,000 ft, both coupled with a satellite communications pod that will automatically relay weather data to ADWA. In addition, the contractor is currently developing a visibility pod enhancement that will sense horizontal visibility. The visibility pod should be available for OUE in early FY 2009.

Weather radar data is vital to the production of timely severe weather warnings. DOD, the Federal Aviation Administration (FAA), and Department of Commerce (DOC)/National Weather Service (NWS) operate and maintain WSR-88Ds within CONUS, and the Air Force operates and maintains WSR-88Ds overseas. Tactical weather radars (TWRs) provide fixed Doppler radar coverage for four major overseas installations not covered by the WSR-88D. Currently Ellason weather radars (EWRs) provide a deployable weather radar capability for worldwide military contingency operations. Based on the desire to consolidate the TWR and EWR programs and improve the overall capability and deployability of fielded weather radars, AFW initiated acquisition of a new Portable Doppler Radar (PDR) in early FY 2008. Following source selection, AF weather anticipates the PDR to undergo OUE in early FY 2009,

Figure 3-DOD-2. Aircraft radar shows the eye of Hurricane Claudette is 25 nautical miles wide and the wall cloud is weakest in the northeast quadrant. (53 WRS Web site)



and fielding to begin later in FY 2009. Weather radar data extracted from air surveillance radars and displayed using the Digital Weather Intelligence Data system supplement primary weather radar data, and provide data from areas without primary weather radar coverage.

The AFRC's 53 WRS, also known as the "Hurricane Hunters," provides another means of collecting vital meteorological data, especially in and around tropical cyclones. Their specially equipped WC-130J aircraft collect temperature, moisture, wind, pressure, and visually observed information at the aircraft location as well as vertical profiles of the atmosphere collected by dropsondes. Hurricane Hunter aircraft penetrate the eyes of tropical cyclones to provide the National Hurricane Center a very accurate center fix location as well as other meteorological parameters, including sea level pressure (Figure 3-DOD-2). In addition to the tropical cyclone reconnaissance, the 53 WRS collects meteorological information to improve wintertime West Coast forecasts and to support scientific field programs when possible.

The Defense Meteorological Satellite Program (DMSP), which provides cloud, upper air, and space environmental data, is a vital source of global weather data used to support combat operations. Onboard sensors provide AFWA and the Navy's Fleet Numerical Meteorology and Oceanography Center with visible, infrared, and microwave imagery, temperature and moisture sounding data, electrically charged particle fluxes, and other specialized space environment data. The DMSP also supplies direct, real-time readouts of regional imagery and mission-sensor data to DOD land-based and shipboard terminals located worldwide (Figure 3-DOD-3).

AF Weather plans to expand the integration of MARK IVB data into cloud models. In addition, AF Weather initiated an effort to expand the MARK IVY program, which consists of equipment to download, disseminate, and analyze meteorological satellite data, to acquire X-band Moderate Resolution Imaging Spectroradiometer (MODIS) data from Terra and Aqua satellites in mid FY 2008. Anticipated to take approximately 18 months, the X-band upgrade will not only provide immediate access to MODIS data, it will also prepare AF weather and AFWA for the NPOESS era as a first step toward the NPOESS Preparatory Project.

The DMSP satellite constellation uses the Operational Linescan System to provide visible and infrared imagery to distinguish between clouds, ground, snow, and water. The Block 5D-2 series spacecraft flies the Special Sensor Microwave Temperature SSM/T-1) and water vapor (SSM/T-2) sounders. Processing algorithms convert the sensed

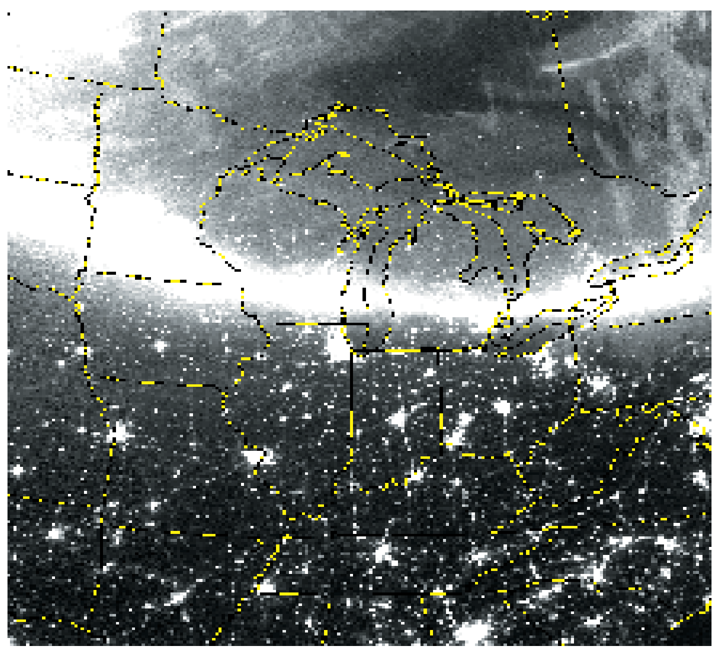


Figure 3-DOD-3. Aircraft radar shows the eye of Hurricane Claudette is 25 nautical miles wide and the wall cloud is weakest in the northeast quadrant. (53 WRS Web site)

data into vertical temperature, moisture, and height profiles of the atmosphere, providing key data for numerical analysis and forecasting. The Special Sensor Microwave Imager (SSM/I) collects data from which rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data can be determined. The Special Sensor for Ions, Electrons, and Scintillation (SSIES), Special Sensor Magnetometer (SSM), and the Precipitating Electron and Ion Spectrometer (SSJ), measure the space environment on the topside of the ionosphere in situ. The Block 5D-3 series spacecraft and sensor suite began service in 2004 with the launch of DMSP Flight 16. These spacecraft add several new capabilities: enhanced microwave imaging and atmospheric temperature/moisture sounding through the Special Sensor Microwave Imager/Sounder (SSMIS); new auroral boundary and electron density measuring capability through the Special Sensor Ultraviolet Spectrographic Imager (SSUSI); and, profiles of upper-atmospheric temperature, electron content, and species densities through the Special Sensor Ultraviolet Limb Imager (SSULI). These are in addition to SSIES, SSM, and SSJ sensors.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) will replace the existing DMSP and NOAA polar-orbiting satellite programs beginning in 2013 and is a joint DOD, DOC, and National Aeronautics and Space Administration (NASA) program. The AF also expects to gain operational experience as well as benefit from the risk reduction planned with the NPOESS Preparatory Program planned for launch in 2010. In January 2006, the program was expected to exceed its approved program baseline by 25 percent. This required the Department of Defense to recertify the program to Congress in accordance with the Nunn-McCurdy Amendment of the 1982 Defense Authorization Act. AF weather provided information on operations and requirements to Integrated Product Team 2 (IPT-2). IPT-2 was charged with assessing alternatives for the program. The certification resulted in a reduced configuration. One of three orbits was eliminated and will be augmented by the polar-orbiting constellation of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The number of satellites was reduced from six to four. Some non-Key Performance Parameter sensors were removed and the Conical Microwave Imager/Sounder was terminated and will be reworked.

In addition to DMSP polar-orbiting data, AFWA receives stored data from the DOC's Polar-orbiting Operational Environmental Satellite constellation and real-time high-resolution data from the DOC's Geostationary Operational Environmental Satellite (GOES) East and West; EUMETSAT's Meteosat-5, -7, -8, and -9 geostationary satellites; and the Japanese Multifunctional Transport Satellite (MTSAT). AFWA currently receives data from NASA's Tropical Rainfall Measuring Mission (TRMM), Quick Scatterometer (QuikSCAT), and Aqua Advanced Microwave Scanning Radiometer-E (AMSR-E) via Direct Asynchronous Transfer Mode (ATM) System-Unclass (DATMS-U). MODIS data is received via the Defense Research Engineering Network (DREN), transitioning to DATMS-U in 2008.

Next generation satellite programs, in particular NPOESS and GOES-R, require that AFWA reengineer the way it receives, stores, and processes meteorological satellite (METSAT) data, as well as how it exposes and delivers that data to internal and external users. AFWA has been partnering with Electronic Systems Center (ESC) on the METSAT Data Exploitation Capability (MDEC) program. The MDEC is the METSAT portion of Weather Data Analysis (WDA). The METSAT database segment, JMSAT, will be delivered in WDA increment 4A, which is expected to be on contract in CY 08. The MDEC will engineer and implement state-of-the-science solutions and define the "to be" enterprise software and system architecture for optimal exploitation of METSAT data from current and future programmed satellites.

Space environmental information is obtained through a combination of ground- and space-based systems. For the near-Earth environment, i.e., ionosphere, ground-based systems provide highly accurate point source verification and specification, whereas space-based systems enable global coverage and theater-wide situational awareness. For solar data, ground-based systems provide reliable observations of the sun in optical and radio frequencies, and space-based observations measure frequencies unobtainable from the ground. Space-based systems provide in situ measurements of the space environment, i.e., solar wind, magnetosphere. AF weather has outlined plans to modernize ground-based space sensing in a space weather implementation plan and is collaborating with U.S. and Allied government and civilian agencies to achieve a robust space sensing capability.

AFWA operates the Solar Electro-optical Observing Network (SEON), a system of ground-based telescopes at Sagamore Hill, MA, Holloman AFB, NM, Palehua, HI, San Vito, Italy, and Learmonth, Australia (Figure 3-DOD-4). This network provides 24-hour observations of solar phenomena at optical and radio wavelengths. A worldwide network of ground-based ionosondes and other sensors provide ionospheric data. The AF manages 14 automated Digital Ionospheric Sounding Systems (DISS) to measure electron density profiles in the ionosphere. AFWA funds a 27 International Ionosonde site database at the National Geophysical Data Center (NGDC) in Boulder, CO. NASA's Jet Propulsion Laboratory operates a complementary global network of over 125 sensors deriving ionospheric line-of-sight total electron content from global positioning system (GPS) signals and provides these data to AFWA's 2 WS Space Weather Flight. In addition, the U.S. Geological Survey operates a network of ground-based magnetometers, primarily in the northern hemisphere, which provides the Space Weather Flight with critical measurements of the geomagnetic field and its variances. The Air Force Research Laboratory at Hanscom AFB, MA, provides ionospheric scintillation data from a global network of 22 UHF and L-Band receivers, supporting AF C2 satellite systems and strategic long-range radar systems.

Figure 3-DOD-4. Solar optical and radio telescopes at Learmonth, Australia. (US Air Force Released)

From space, the GOES satellites provide real-time solar X-ray, charged energetic particle, and geomagnetic data through the Space Weather Prediction Center (SWPC). The Solar X-Ray Imager, aboard GOES-12, monitors solar emissions in the X-ray portions of the solar spectrum and provides near real-time display at AFWA and the SWPC. DMSP, NOAA, and other DOD satellites provide charged energetic particle data in low-Earth and geosynchronous orbits. Additionally, the AF leverages space-based data from NASA and other agencies. For example, NASA's Advanced Composition Explorer satellite provides real-time solar wind data critical for forecasting geomagnetic disturbances and their impact to warfighter communications.

Analysis and Prediction

Effective analysis of collected terrestrial and space weather data enables identification of environmental features and conditions that may affect air, space, and land operations and thus require subsequent monitoring. From that analysis, detailed forecasts are developed through a combination of computer models and skilled human intervention.

AFWA's 2 SOS is the AF's main automated production capability for global space and terrestrial weather analyses and forecasts. Worldwide conventional weather data are relayed to 2 SOS and combined with civil and military meteorological satellite data to construct an integrated environmental database. Computer programs further process the data to construct models of the atmosphere and forecast its future behavior.

The Global Theater Weather Analysis and Prediction System (GTWAPS) is the AFWA hardware enclave (IBM Scalable Parallel Computing and pSeries® servers) used to run most meteorological models at AFWA. The key software component of GTWAPS is a theater analysis and forecast model which provides fine-scale forecasts (Figure 3-DOD-5). AFWA transitioned from Mesoscale Model version 5 (MM5) to the Weather Research and Forecasting (WRF) model as its operational theater scale model in 2008. WRF has the ability to interchange different microphysics modules within the model. AFWA is leveraging this capability to tailor model output for different worldwide operational theaters,

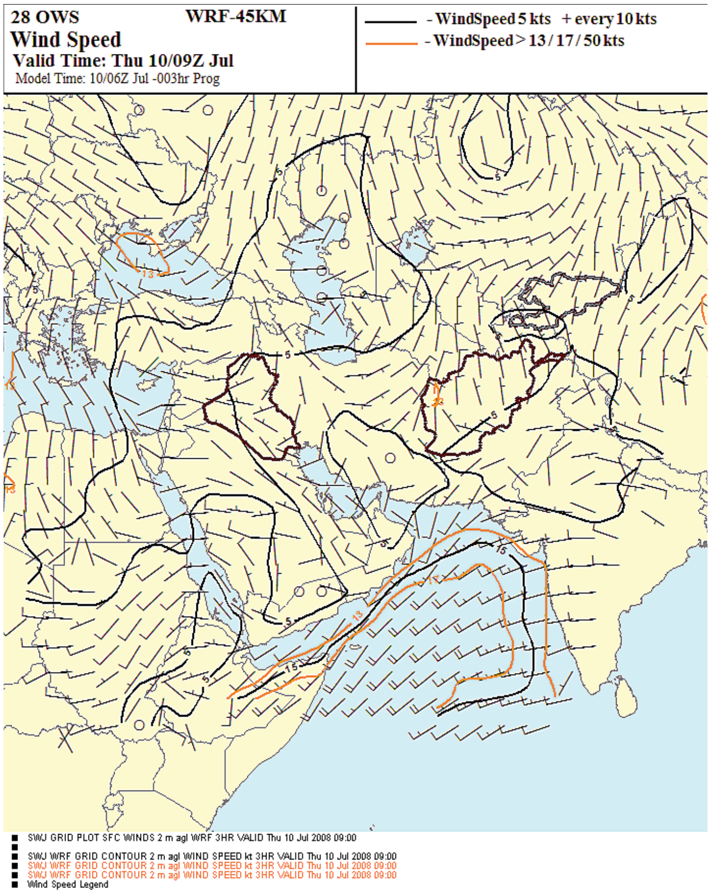



Figure 3-DOD-5. Joint Air Force and Army Weather Information Network (JAAWIN) provide reachback capability for deployed weather forces. This 3-hour forecast of surface winds over Southwest Asia was generated from AFWA's 45-km WRF (AFWA Web site)

while leveraging NCEP's WRF model output for the Alaska and CONUS regions.

During Operations ENDURING FREEDOM and IRAQI FREEDOM, AFWA initiated various model window locations and resolutions as mission requirements dictated. The highly responsive nature of the WRF model, and the way AFWA employs it, permitted new contingency windows to be operational within hours. Advancements in cloud modeling have enabled GTWAPS to produce high-resolution products that have become a mainstay of weather data during the continuing Global War on Terror.

Ongoing modernization initiatives at AFWA include the Space Weather Analysis and Forecasting System (SWAFS) and the WDA program. SWAFS will integrate additional space weather data sources and execute next-generation space weather models for DOD and IC operations. WDA will continue the modernization of AFWA as a key component of the AFWWS. The transformed AFWA will provide standardscompliant hardware and software tools, a central 4-D database, and a classified processing environment to modernize the AFWWS communications and data processing infrastructure. WDA provides a significant increase in the database capability by standing up Joint DOD-approved meteorological and oceanographic (METOC) database segments, promoting interoperability among data sharers. WDA, using the Joint METOC segments and the Joint METOC Broker Language (JMBL) for web services, will improve the interoperability with DOD C2 and command, control, communications, computer, intelligence, surveillance, and reconnaissance (C4ISR) systems by providing a common interface to request the wide range of weather information. In addition, WDA-developed components, including the Consolidated Dissemination Capability (subscription services), are reusable within the OWS. This reusability will allow OWS-unique data to become part of the overall AFWWS 4-D database.

Also in the area of analysis and prediction, AF weather is modernizing cloud forecasting capabilities to support AF and Army operations and to enable "find, fix, track, target, engage, and assess", by leveraging the Aerospace Corporation, NWS, NCAR and ARL. These efforts, combined with those underway to improve the Cloud Depiction and Forecasting System (CDFS) II capability, will ensure the AF continues as a center of excellence in cloud forecasting.

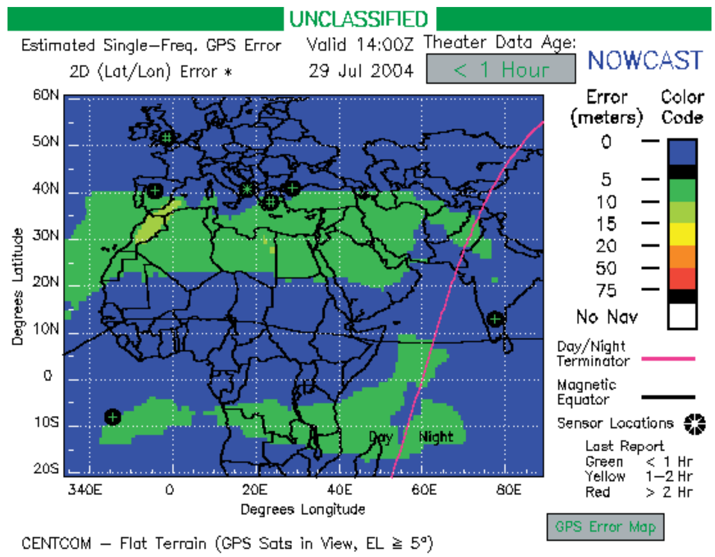
AFWA's 2 WS METSAT Flight analyzes imagery, produces rapid response, tailored METSAT imagery for DOD contingency operations, and generates automated METSAT imagery products for web-based distribution to DOD users. The flight also serves as the DOD focal point for volcanic ash plume detection, advisories, and trajectory forecasts; and provides back up for both Joint Typhoon Warning Center (JTWC) satellite operations and the DOC's Washington Volcanic Ash Advisory Center. In addition, the METSAT Flight produces worldwide snow and ice cover analyses to update and refine the snow depth database and generates customized snow depth and dust event analyses for contingency areas. The flight also develops new capabilities to display and visualize satellite imagery on workstations and infuses state-of-the-art techniques into improved imagery analysis. Finally, the flight recently stood up a cell that focuses on SW Asia, highlighting areas of cloud, dust, and other obscurants.

As the sole source of DOD space environmental characterization and forecasting, AFWA's Space Weather Flight partners with NOAA's Space Weather Prediction Center to meet the Nation's military and civilian space weather needs and provide a suite of automated and manually tailored analyses and forecasts (including advisories and warnings) of space weather phenomena that affect military operations and IC activities. Similarly, forecasts of signal fades due to space weather effects on UHF satellite communications links provide valuable planning information to improve C2 capabilities. Further examples of model output informational products include Single-Frequency GPS Receiver Error maps (Figure 3-DOD-7), UHF Satellite Communication Scintillation maps (Figure 3-DOD-8), HF Illumination maps (Figure 3-DOD-9), and Radar Auroral Clutter maps. These products assist warfighters in determining and mitigating space weather impacts to their systems as well as in exploiting enemy space weather susceptibilities for possible asymmetric advantage.

The 2 WS Space Weather Flight employs a suite of state-of-the-art space weather models to specify current solar and global characteristics, extrapolate space weather phenomenon to areas of the globe where observations are not currently available, and to forecast future conditions. These models use available observations and include both climatology-based and physics-based algorithms. Information on the more significant models employed is included in this paragraph. A Kp analysis and prediction algorithm provides realtime analysis of Kp and 1- and 4-hour predictions. A Dst prediction algorithm provides a 1-hour Dst forecast. The Global Assimilation of Ionospheric Measurements (GAIM) model provides large scale, global ionospheric specification every 15 minutes and a 24-hour forecast capability every hour. The climatology-based WIDEBAND model provides scintillation forecasts. The flight uses the Magnetospheric Specification and Forecast Model to specify and predict (for 3 hours) the lower energy particle environment. The Radiation Belt Environments model provides specification of the higher energy particle environment. The relativistic Electron Prediction model provides a 27-day prediction of relativistic electron behavior at geostationary altitude. For the solar wind, the flight uses the Hakamada-Akasofu-Fry solar wind model, capable of producing a 96-hour forecast of solar wind parameters, including the tracking of Coronal Mass Ejections. Several other applications are also employed to calculate other important space weather related parameters.

The 14 WS fills a critical role in AF weather's core processes of analysis and prediction. The 14

Figure 3-DOD-6. Single-Frequency GPS Receiver Error Map (visualization by HQ AFWA)



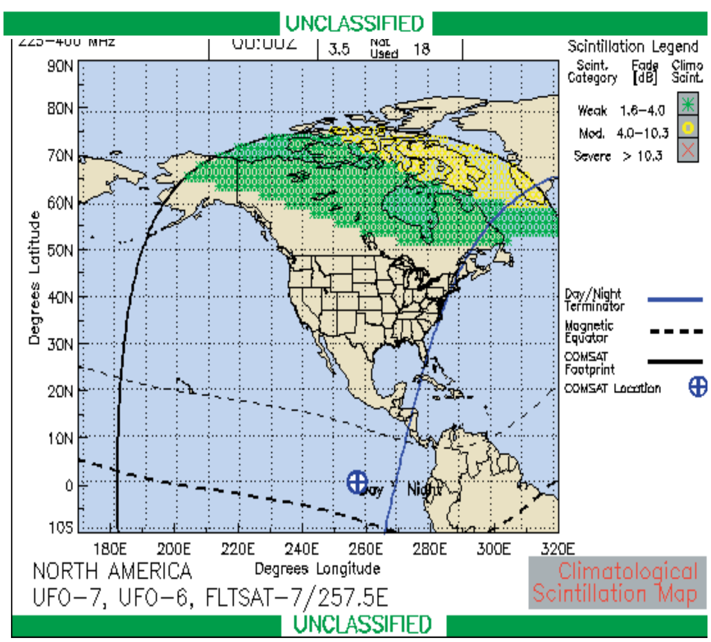




Figure 3-DOD-7. UHF Satellite Communications Scintillation Map (visualization by HQ AFWA)

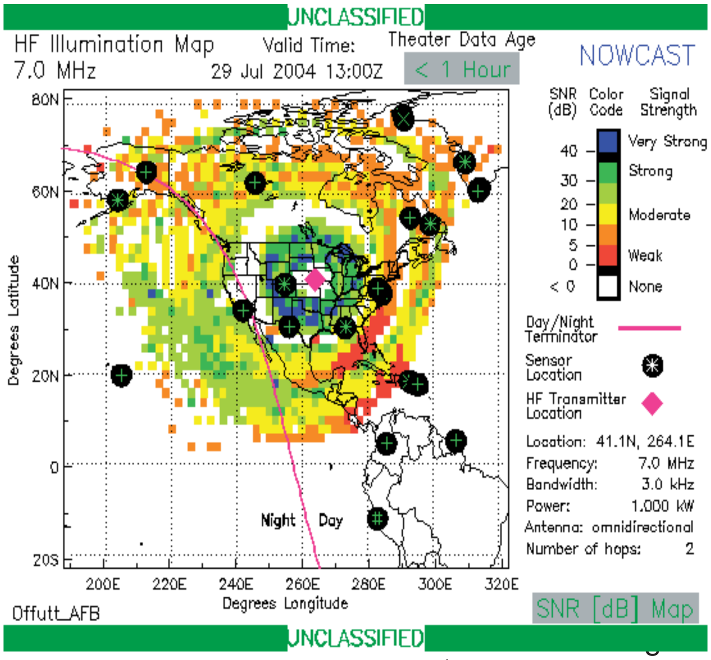


Figure 3-DOD-8. HF Illumination Map (visualization by HQ AFWA)

phenomena for points around the globe (e.g., Operational Climatic Data Summaries and Wind Stratified Conditional Climatologies). Leveraging research from the Naval Postgraduate School and other national and international resources, forecasters produce seasonal outlooks extending to 75 days for Kabul, Afghanistan and Baghdad, Iraq, and continue to investigate new methodologies to stretch forecasts out to six months. Third, 14 WS exploits modeling and simulation technologies, including Advanced Climate Modeling and Environmental Simulations (ACMES) and the Environmental Scenario Generator (ESG), to produce modeled climate statistics and gridded climatologies, and simulated environmental scenarios respectively, to support training and exercises. Fourth, 14 WS employs the Point Analysis Intelligence System (PAIS) to produce historical, real-time, and forecast vertical profiles for any location in support of the Intelligence Community. Fifth, 14 WS oversees the 250,000 documents archived in the Air Force Weather's Technical Library.

Also in the area of climatology, AF Weather is developing a 6-month forecast capability by leveraging research conducted by AF and Navy officers at Monterey, work already accomplished by NATO allies in using climatology, and advances in teleconnections (i.e., El Nino/Southern Oscillation, North Atlantic Oscillation, Southern Annular Mode), with a goal of providing planners a risk management tool to positively impact operations.

The Air Force Director of Weather carries out the DOD Air and Space Natural Environment Modeling and Simulation Executive Agent (ASNE MSEA) responsibilities of managing, coordinating, and implementing all aspects of modeling and simulation relating to the Air and Space Natural Environment domain to include, but not limited to, planning, programming, monitoring, and reporting across all DOD components in accordance with the Under Secretary of Defense for Acquisition, Technology, and Logistics Memorandum to the Secretary of the Air Force, designating the Department of the Air Force as the MSEA for air and space natural environment representations. The DOD ASNE MSEA ensures DOD communities who use simulations for their training, acquisition, testing, planning, experimentation, and analysis have the right tools, infrastructure, and databases necessary to represent the air and space natural environment and its effects. To do this, the DOD ASNE MSEA works closely with both government and industry agencies such as AFWA, National Geophysical Data Center, and others to develop and provide the needed environmental tools and data. The Executive Agent keeps abreast of both current and emerging capabilities within the field of meteorology and the space environment, enabling identification of gaps in these capabilities and solutions to meet DOD environmental requirements for live, virtual, and constructive simulations. Often, the MSEA is required to champion development and transition of new technologies at government resource centers like those mentioned above. The DOD ASNE MSEA also works closely with the Ocean MSEA (Navy, CNMOC) and the Terrain MSEA (National Geospatial-Intelligence Agency, NGA) to ensure a consistent, integrated natural environment is represented in the synthetic environment of a simulation. The ASNE MSEA's Environmental Scenario Generator (ESG) facilitates assembling a consistent, integrated natural environment from distributed centers nationwide. The core ESG system was transitioned to the 14 WS for long-term operational support of the DOD, with future capabilities being integrated from the National Geophysical Data Center (Boulder, CO), the Naval Oceanographic Center (Stennis, LA), and future NGA centers of excellence.

OWSs are AF weather's regional/theater

analysis and forecast centers for Air Force and Army operations. Each OWS generates a variety of products: hazard charts; drop zone, range, and aerial refueling track forecasts; fine-scale target forecasts; airfield forecasts; and weather warnings, watches, and advisories, for Air Force and Army installations within its AOR. The current production system, OPS II, is a legacy system being replaced by JET Increment 1 beginning summer 2008. JET will replace this component of the Forecasting System 21st Century (FS-21) program, providing necessary computer hardware and software throughout the AFWWS, and becoming the OWS's primary production tool. JET will replace a hybrid of software, databases, servers, and workstations. Increment 1 will deliver a common environmental toolkit across the weather enterprise while Increment 2 will focus on weather exploitation tools and Common Operational Picture (COP) visualization of data and effects. These developments go hand-in-hand with AF weather's TTP development efforts, and provide an AFWWS standard for production and dissemination of weather information to supported forces.

Provide Actionable Environmental Impacts Information to Decision-Makers

To provide actionable environmental impacts, AF weather forces continually improve the core processes of tailoring and integration.

Tailoring

Once centralized weather units create a depiction of the past, current, and future state of the natural environment, AF weather forces directly supporting decision-makers tailor the information to identify impacts to operations, personnel, weapons and weapons systems, and tactics. These weather forces then help decision-makers mitigate these effects through appropriate actions such as routing a flight to a new target, selecting a different weapons load, or adjusting the time of attack.

N-TFS, another component of FS-21, to be replaced by JET, provides garrison and deployed weather forces with the meteorological tools to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and AF operations, C2, and support forces worldwide. Additionally, N-TFS ingests data from AF and indigenous observing sources, which then are forwarded to OWS/AFWA for further dissemination and incorporation into centrally produced model output.

JET will provide a single workstation that will eliminate redundancies and/or inefficiencies and ultimately extend, consolidate and/or replace the OPS II, Joint Weather Impact System (JWIS), N-TFS, and the weather effects decision-aids portion of the Integrated Meteorological System (IMETS). JET enhances warfighter awareness of the natural battlespace environment by ensuring accurate, timely, relevant, and consistent terrestrial and space weather and weather impacts information is available and accessible by appropriate personnel and processes. Furthermore, JET enhances the accuracy and utility of terrestrial/space weather and oceanographic information and operational impacts by enabling the forecaster and/or forecast process to incorporate Geographic Information System (GIS) capabilities (to include a standard high-resolution topographic database), forecasting rules of thumb, and operational thresholds into weather and weather impact products. Later spirals of JET will perform its functions by interfacing with information contained in the Virtual Joint Meteorological and Oceanographic Database via common-user-communications, and will integrate with joint and coalition C2 and mission planning systems by enabling machine-to-machine exchange of METOC and C4ISR data and information to meet operational, planning, and execution requirements. Raytheon was awarded the JET contract on 28 March 2006. Fielding of the first JET increment is scheduled to begin in summer 2008 with an expected delivery of all JET capabilities by FY 13.

Tactical Decision Aids (TDAs) provide warfighters an automated way to "visualize" environmental impacts on operations. These tools, which continue to be integrated into C2 systems (e.g. mission planning systems) include Target Acquisition Weapons Software (TAWS) (Figure 3-DOD-6), Infrared Target Scene Simulation (IRTSS) and Tri-Service Integrated Weather Effects Decision Aid (T-IWEDA). The Air Force Research Laboratory (AFRL), the Navy's Space

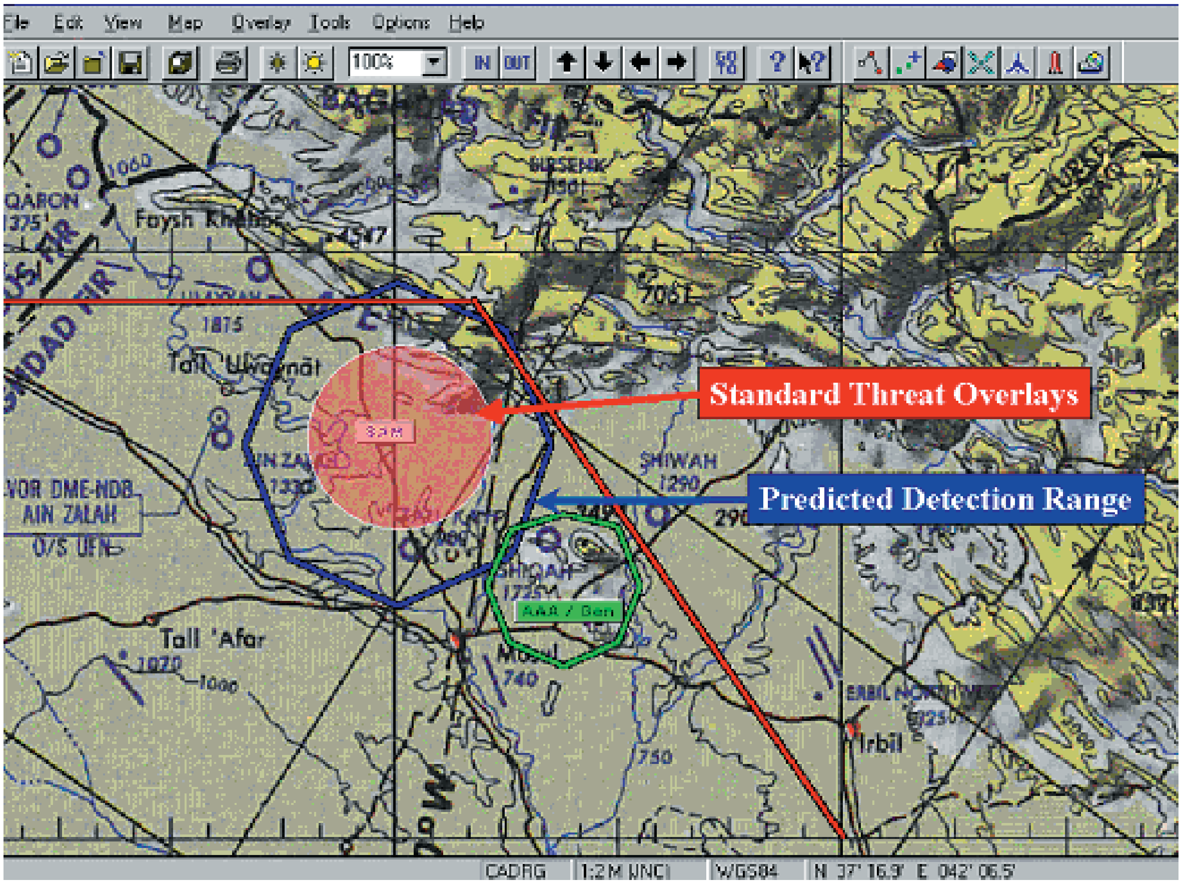



Figure 3-DOD-9. Target Acquisition Weapon Software (TAWS) integrate meteorological conditions and environmental parameters to enhance the mission planning process and increase aircrew situational awareness for mission execution. (US Air Force Released)

and Naval Warfare Systems Command, the Navy Research Laboratory (NRL), and the Army Research Laboratory (ARL) are developing these modular programs. TAWS provides a joint mission-planning tool to combine platform, weapon, target, background, and weather impacts to depict three-dimensional target acquisition and lock-on range and recognition range versus time. This includes prediction of environmental impacts on night vision goggles and low light-level systems used by air, naval, and ground forces to execute nighttime operations. IRTSS uses detailed terrain information and multi-spectral imagery with TAWS weather inputs to generate forecast target scene images for mission rehearsal. The T-IWEDA uses environmental data with force, mission, and/or individual weapons rules of engagement or performance parameters to automatically generate mission-impact forecasts for large-scale planning efforts such as air tasking order preparation. TAWS, IRTSS, and T-IWEDA integrate environmental impacts into the mission execution forecasts for C2 and mission planning (MP) systems throughout the military planning and execution cycle. The TDA program continues adding weapons systems and targets at the request of users from the Services. Additional decision aids in development or in coordination include the airborne laser (ABL) atmospheric decision aid to support ABL development and operations and a common radio frequency (RF) system performance prediction capability based on U.S. Navy software.

AFWA's 2 WS Special Support Operations Flight generates a myriad of products ranging from air refueling forecasts, to detailed mission control forecasts, to weather impacts for SOF operations, and distributes this information via secure media to support worldwide Joint SOF operations. The flight also provides tailored meteorological information for end-to-end planning at U.S. Special Operations Command (USSOCOM), Service component special operations commands, and theater special operations commands. The Special Operations Weather Flight (SOWF) is continually involved in global military operations, including OEF and OIF. Additionally, the SOWF includes the American Forces Network Weather Center, which provides worldwide, broadcast-quality public weather services and planning forecasts through the American Forces Radio and Television Service to over 1,000,000 Department of Defense and Department of State (DOS) personnel and family members stationed overseas. AF Special Operations Command will be standing up a squadron to assume support to SOF operations in CY2008-09.

The 2 WS Intel Flight provides detailed global cloud analyses and forecasts to the IC. The flight provides worldwide mission-tailored planning and execution forecasts for IC agencies at security levels up to Top Secret/Sensitive Compartmented Information (TS/SCI). The flight also serves as the focal point for AFWA Special Access Program (SAP) requirements; ensures the IC and other SCI and SAP meteorological requirements are integrated into AFWA programs; monitors and evaluates accuracy and timeliness of centralized weather services to the IC; and interfaces with the Department of Defense and IC regarding weather services and the exploitation of weather information.

The Air Force provides meteorological and space weather products to the Nation's space and missile programs, including a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center (KSC). The Air Force also provides tailored forecasting for NASA's manned and unmanned launches and for commercial launches from KSC. In addition, the Air Force provides specialized meteorological information for the Air Force Western Range at Vandenberg AFB, California; the Pacific Missile Range, which includes Point Mugu and San Nicholas Island, CA, and Barking Sands, HI; White Sands Missile Range, NM; Kwajalein Missile Range, Republic of the Marshall Islands; and other DOD research and test facilities as directed.

The Air Force also provides agro-meteorological support to the U.S. Department of Agriculture's Foreign Agricultural Service and other similar users. The output includes diagnostic soil hydrology and other meteorological information pertinent to crop growth and yield estimation as well as to trafficability and rudimentary flooding estimations.

Integration

Tailored environmental information and operational impacts are of little use to decision-makers if the information and/or impacts are not integrated into the shaping, planning, execution, and sustainment of air, space, and land operations. The AF employs a blend of information technology (IT), including automated machine-to-machine (M2M) interfaces, and personnel embedded at the right echelons with decision-makers, to integrate timely, accurate, relevant, and consistent weather and weather impacts information into decision-making processes. Since timeliness is critical to effective integration, AF weather operations rely on robust, assured communications for dissemination.

AFWA receives alphanumeric weather data, parses it 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 dedicated circuits, NIPRNET, and satellite broadcast facilities. As AFWA transitions to WDA-developed components including the Consolidated Dissemination Capability (subscription services), the pre-staging of tailored bulletins will be minimal as users will be able to generate their own data sets.

High-speed communications between large Department of Defense 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 these data to OWSs.

Forecaster-developed products and gridded data sets are distributed from AFWA via the Weather Product Management and Distribution System to base/post-level weather forces around the globe using the DOD's NIPRNET and SIPRNET.

AFWA 2 SOS operates a website on the NIPRNET known as the Joint Air Force-Army Weather Information Network (JAAWIN). JAAWIN provides worldwide access to numerical model forecasts, satellite imagery, forecaster-in-the-loop products, and text bulletins, and includes links to all OWS Web sites. Additional products are available to classified users via JAAWIN-Secret (JAAWIN-S) and JAAWIN-Sensitive Compartmented Information (JAAWIN-SCI).

JET also replaces JWIS, which offers another means of making tailored weather information available to DOD users. Currently, JWIS provides a link to weather information from both Air Force and Navy sources for exploitation by C2 systems and applications.

Although information technology continues to enhance the integration of weather and weather impact information into decision-making processes, well-trained weather professionals are still essential. Designated AF weather personnel serve on the staffs of operational Air Force, Army, and Joint force units worldwide. In this capacity, they identify weather-sensitive areas of the operation and provide expert advice to help mitigate weather impacts on personnel, platforms, weapons and weapons systems, and tactics. The ultimate goal is to identify opportunities for an asymmetric advantage over our foes, i.e., when enemy force capabilities are more severely degraded by weather than those of friendly forces.

For AF operations, these weather professionals are normally assigned to a flight under an operations support squadron in a flying wing; however, individuals from the weather flight are integrated into flying squadron mission planning and execution processes. In this capacity, they infuse critical weather information at key points in the decision cycle to help aircrews maximize wartime capabilities, enhance flight safety, and optimize training effectiveness. Weather experts are also assigned to weather specialty teams in air and space operations centers. This cross-cutting team integrates all-source actionable environmental information at key decision points of air and space operations planning, execution, and assessment. Armed with this information, decision-makers can balance operational risks against mission need to optimize timing, tactics, target and weapons selection, and other factors affecting air and space operations. Finally, AF weather experts are integrated into a variety of other unique mission areas, such as space launch support and RDT&E activities. In each capacity, these specialists enable the supported organization to minimize or alleviate weather impacts to the mission. For instance, to avoid potentially devastating storms, space launch weather personnel may advise decision-makers to adjust launch timing, while RDT&E weather personnel may identify potential weather sensitivities to system developers to ensure a safe, effective design.

Likewise, Army weather requirements are incorporated into the AF's overall weather operations concept. AF weather forces are integrated with Army intelligence staffs. The Army trains and educates Air Force personnel on Army organizations, concepts of operations, and the weather sensitivities. AF weather forces are currently habitually aligned with echelons above corps, corps, divisions, separate brigades, aviation brigades, armored cavalry regiments, ranger regiments, and Special Forces groups (as well as subordinate battalions deployed at forward operating bases). Over the next few years, AF weather support to the Army will undergo significant transformation as the Army transitions from a division-centric force based on large standing organizations to a brigade-centric force based on smaller, modular organizations.

Air Force Weather is targeting a net-centric architecture by 2011. Employing net-centric concepts ensures the environmental information will be readily discoverable and exploitable by all decision-makers, both anticipated and unanticipated, by making the information visible, accessible, understandable, and interoperable throughout the DOD. Core Enterprise Services (CES) will provide the minimal set of enterprise web services to enable enterprise-wide sharing, reuse, and interoperability of information and processes. Catalogs will be stored in shared spaces and use DOD-approved standard formats so all users can employ established CES search tools to rapidly discover the data and services for potential use.

JMBL will be the interface that enables users to access information in the Global Information Grid. Extensible Markup Language will be the standard and allow different applications from different sources to communicate with each other without time-consuming custom coding. This will break down stovepipes and enable standard application interoperability, integrate functionality of disparate systems into seamless operations, and be ideal for M2M communications.

AFWA's Weather Data Analysis Capability (WDAC) program, which began the migration to the DOD Joint METOC Data Architecture to support dynamic, fast-paced M2M operations, was merged with the MDEC in early 2008 to form WDA. Combining these two programs allowed AF weather to save overhead, and prevent creating duplicative capabilities. This architecture provides for authoritative, timely, relevant, accurate, and consistent environmental information, accessible via a common web-service interface from anywhere on the Global Information Grid. The WDA program modernizes the AFWA production center and 14 WS infrastructure, providing a centralized net-centric reach-back source for worldwide space and atmospheric weather information, to include environmental intelligence data to C2, C4ISR, MP, and mission support systems such as the Joint Mission Planning System. This vision is accomplished through implementation of the JMDB, is the common mechanism for users to access the JMDB for M2M operations.

WDA through increment three includes JMGRID (gridded analysis and forecast data); JMOBS (conventional observation data); JMAN (alphanumeric messages and bulletins); and JMPLAT (fixed and mobile weather station platform data); Joint METOC Space Environment and Solar Segment (JMSESS) (i.e., space related alphanumeric, imagery, and non-METOC data) prototype; a JMIM (Joint METOC Imagery) database segment prototype in support of non-geolocated objects; Gridded Consolidated Dissemination Component for JMOBS, JMAN, non geolocated images, geolocated with an intuitive interface and local authentication capability. The next WDA increment is scheduled to be on contract in fall 2008.

## RESEARCH INITIATIVES

The overarching objective of the Air Force meteorological and space environmental technology transition program is to provide capability designers, operational weather personnel, and weather information users the technology and tools to gain and maintain the advantage over a potential adversary. Capability needs in the atmospheric and space environment sciences are articulated in Air Force weather's Joint Capability Document, Capability Review assessments, the AFW and AFWA Strategic Plans, the AFW Operations Functional Concept and Enabling Concepts (Characterize the Environment, Exploit Environmental Information, and Net-Centric Operations), and supporting concept and implementation plans. AF weather also strives toward improvements through cooperative development and testing agreements both with other governmental agencies and laboratories, as well as for-profit companies. Additionally, both AFIT and the Naval Postgraduate School offer AF graduate students in the atmospheric and space environmental sciences an opportunity to research topics of immediate operational interest to the Service. AF weather has recently fielded an IOC version of the Utah State University (USU) developed GAIM model. AF weather continues to work with USU toward the fielding of a FOC full physics version of the GAIM model sometime in FY09-10. In addition, AF weather will be working during FY08 to fully integrate ultraviolet sensing instruments (SSUSI, SSULI, and GUVI) into space weather operations. This effort will include model integration, visualization, and validation efforts.

In applied meteorological R&D, the AF is improving CDFS techniques by doubling the resolution, integrating geosynchronous METSATs into the cloud analysis, using a new cloud interpretation scheme, and blending numerical weather prediction with forecast cloud advection techniques. The AF 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. In addition to internal efforts, AF weather will continue to rely on collaboration with, and leveraging efforts of, other federal meteorological agencies, research labs, and universities to further improve CDFS system performance and meet other research needs.

### MODELING FOR AIR FORCE AND ARMY OPERATIONS

The WRF model is the next generation community model and is another area of AFWA participation in research and development in collaboration with NCAR, NOAA's NCEP, NOAA' s Earth Systems Research Laboratory (ESRL), the University of Oklahoma's Center for the Analysis and Prediction of Storms, and others. AFWA initially implemented WRF operationally in 2006 and will continue with sponsorship and funding of development at NCAR and ESRL, test and evaluation of real-time runs of the WRF prototype, and will lead the Land Surface Model (LSM) Working Group while participating in others. The LSM analyzes the current state of the land surface to provide information to DOD and civilian agencies, and through coupling with WRF, will improve forecasting performance in the low levels of the atmosphere. This allows AF weather forces to provide better forecasts for low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also allows for assessment of trafficability for ground forces.

AFWA is in the process of identifying a future capability called the Ensemble Prediction System (EPS). EPS output will help AF Weather personnel to provide better forecasts for the warfighter with increased confidence, particularly at the tactical level. The ongoing Joint Ensemble Forecast System (JEFS) prototype effort is laying the groundwork to construct an operational EPS and the first non-operational JEFS products are being produced daily at AFWA as part of the JEFS test in the U.S. Pacific Command (USPACOM) and U.S. Central Command (USCENTCOM) AORs.

There are two distinct components of EPS, with one being coarse-scale global and the other fine-scale regional. The AF concept calls for leveraging NCEP's and the Navy's global and CONUS capabilities with NWS and FNMOC running the global models. AFWA and FNMOC are currently conducting a 1-year proof-of-concept test which includes a global and fine-scale prototype, with a 5km, 10 member set over Central Command's Area Of Responsibility and Korea. Expected benefits include more objective Operational Risk Management (ORM) decisions by warfighters enabled by the additional information provided through ensemble forecasts. Dependant on the success of JEFS, AFWA will begin operational transition of EF in about 2010.

In addition, AF weather is partnering with the NWS and the Navy in the National Unified Operational Prediction Capability (NUOPC) project. This partnership exists to enable a Tri-Agency joint global atmospheric ensemble forecast system. NUOPC is an integration of ongoing efforts coordinated by a Tri-agency management organization. The NUOPC vision is a National NWP system with interoperable components built on common standards and framework (Earth System Modeling Framework (ESMF)) with managed operational ensemble diversity and a national global NWP research agenda to accelerate science and technology infusion.

## ATMOSPHERIC OPTICAL TURBULENCE

Electro-optical (EO) systems are adversely affected by optical distortions caused by 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 capability whose performance is highly dependent on the variations of the meteorological conditions that produce optical turbulence. 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 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 world-wide. Horizontal measurements by the aircraft augment the vertical profiling by balloons to assist in the development of the detailed knowledge required to support new EO systems.

## UNITED STATES WEATHER RESEARCH PROGRAM (USWRP)

USWRP's mission is to accelerate forecast improvements for high-impact weather phenomena and to facilitate full use of advanced weather information. AF weather first entered into discussions with USWRP in 2001 to explore expanded participation in the program. The program currently focuses on landfalling hurricanes, heavy precipitation, and socio-economic impacts. The AF is eager to leverage future efforts in the areas of observing, assimilation strategies for data-sparse regions, and urban forecasting to increase warfighters' abilities to anticipate and exploit the weather. AF weather is already committed to the USWRP-affiliated community development of the WRF model and will continue its USWRP involvement during the coming fiscal year.

## AIR FORCE RESEARCH LABORATORY (AFRL)

AFRL supports AFWA by executing research conducted by external agencies and by conducting inhouse research on space weather. AFRL works with AFWA to execute the research portion of AFWA's forecasting and modeling program. AFRL coordinates with government agencies (e.g., NASA), Federally Funded Research and Development Centers (e.g., NCAR), and private corporations to fund research in support of weather model development. In space weather research, AFRL programs focus on ionospheric impacts to radio frequency systems, charged particle specification and forecasts, solar disturbance prediction, and neutral density effects on Low-Earth Orbit spacecraft. Working closely with the DMSP System Program Office at the Space and Missile Systems Center, under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include: space environment sensors on the DMSP spacecraft; state-of-the-art ground-based scintillation detectors; total electron content sensors; DISS/NEXION; SEON; and the Operationalized Space Environment Network Display suite of web-based products. In addition to the AFRL research portfolio, AF weather 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, John Hopkins Applied Physics Laboratory, the Naval Research Laboratory, NASA, NOAA's Space Weather Prediction Center, and the Community for Integrated Space Modeling.

AF weather is also working with AFRL design teams on Distributed Mission Operations (DMO). They are operationally testing and evaluating weather impacts, messages, and feed during DMO exercises and test-events as they identify wargame program requirements.

## ARMY RESEARCH LAB (ARL)

AF Weather is leveraging ARL's nested weather running estimate, also known as nowcast, for the 0-3 hour forecast through local tailoring of theater grids and using fine scale models with 1-km grid resolution. These theater and nested grids will be used in decision aid tools such as Tri-Service IWEDA, Aircraft Weather Routing and EO/Infrared tools such as TAWS to determine weather impacts/effects at each grid point. AF Weather is also researching how to take advantage of ARL's capabilities in battlefield sensing and capture, store and use environmental observed data from UAS, aircraft LIDAR and Future Combat Systems vehicles. Another area where AF Weather is joining forces with ARL is with integrating the UAS routing/impacts tool into the operational realm.

## NEXT GENERATION AIR TRANSPORTATION SYSTEM (NextGen)

AF weather has taken the lead in DOD weather support to the Next Generation Air Transportation System (NextGen) Joint Planning and Development Office (JPDO) Weather working Group (WWG). The basis of the NextGen Wx CONOPS is a virtual 4-Dimensional (space and time) weather data base that covers the National Airspace System (NAS) called the 4-D Wx Data Cube. This cube will contain all the weather data, information and products necessary for supporting aviation operations including observations and forecasts from both federal and commercial sources. A subset of the 4-D wx data cube will be a common, consistent, data set called the 4-D Wx Single Authoritative Source (SAS) that is used to create a common weather picture for federal aviation decision-makers. This SAS will be open and available to all NAS users. The 4-D Cube and SAS will be net-enabled for machine-to-machine data exchange. This whole concept is called the NextGen Net-Enabled Weather (NNEW). AF weather is working closely with the JPDO, NWS and FAA on this concept. AF weather is providing net-centric lessons learned and technology, such as JMBL, to help this program along. In 2007, AF weather participated in the development of a JPDO weather policy paper and weather functional requirements document. All of these endeavors will not only benefit NextGen but will also contribute to improving the weather data available to integrate into military C2 systems.

In the area of C2 integration AF weather is also working with the AF Combat Support Office to develop the capability to overlay weather on the predator COP. AF Weather has partnered with the National Geospatial-Intelligence Agency to develop method to present extensible markup language tagged weather data into Google Earth format.

AF weather submitted a proposal for reutilization of High Performance Computing Modernization Program (HPCMP) assets, the Linux Networx Evolocity II Cluster (JVN) or IBM Regatta Power 4+ system (KRACKEN), in June 2008. Under the proposal, AFWA will work closely with ARL, NCAR, and NASA to make maximum use of this HPCMP equipment to further research the cutting edge science of stochastic weather forecasting for operational exploitation. AFWA, with its ARL partners, will develop and test very high-resolution wind field models to produce highly resolved flow patterns in complex battlefield terrain to enable improved Chemical, Biological, Radiological, and Nuclear dispersion forecasts in support of the Defense Threat Reduction Agency and AF and Army decision-makers. AFWA will test the WRF Chemistry model to characterize aerosol and photochemical processes that degrade the combat effectiveness of weapons and defense systems. AFWA, with its NASA partners, will develop and test a very high-resolution land data assimilation system, called Land Information System, and drive cloud characterization capabilities to resolutions on the order of 1 KM to significantly improve support for AF, Army, Special Operations, and IC operations. AFWA will work with NCAR to develop Auto Vortex Following WRF capabilities for use by the JTWC to improve typhoon forecasts. Finally, AFWA will develop, test, and integrate full physics GAIM to improve space weather situational awareness and support to combat operations.

In conclusion, through a continuous process of review and definition, the Air Force documents its requirements for research aimed ultimately at providing timely, accurate, relevant, and consistent weather information to the warfighter today and in the future. In meteorological R&D, AF weather is committed to continued development of the WRF model and collaboration with others to the benefit of the warfighter and the nation. Space weather and cloud forecasting research will continue to facilitate the transition of required capabilities to operational use at minimum expense.

## OVERVIEW

The U. S. Navy's Oceanography and Meteorology Program (NOP) provides global meteorology, oceanographic, Maritime Geospatial-Environmental Information & Services and ocean surveillance critical for safe and effective operations of the Navy and Marine Corps and the Department of Defense. Its mission is to protect the Fleet, shape the battlespace and maximize warfighting capability. The program in-cludes oceanography, bathymetry, hydrography, meteorology, acoustics, geophysics, astrometry, geospa-tial information and precise time.

Naval METOC underpins every aspect of naval operations and warfare. It provides an affordable and sustainable competitive advantage to the Nation and protects the substantial National investment in both afloat and ashore force structure.

The NOP, which is supported by ocean engineering, operational supercomputing and operations research, in recent years reinvented itself to meet the warfighting needs of the operators and the fiscal needs of today's Navy.

Increasingly, costs are leveraged in the Joint, interagency and international arenas to deliver capabilities at a shared cost. The NOP is the Department of Defense's global Numerical Weather Forecasting Capability and it partners with Air Force weather in the areas of flight weather forecasting, Joint operations, information management and acquisition programs. It also has strong relationships with all five direc-torates in NOAA.

Figure 3 – DOD 10. Aerographer's Mate 1st Class William Palmer releases a weather balloon from the flight deck aboard the amphibious assault ship USS Peleliu (LHA 5). (US Navy Released)

## ORGANIZATION

The Commander Naval Meteorology and Oceanography Command is an Echelon III command reporting to the U.S. Fleet Forces Command (USFF). Its resource sponsors are OPNAV N4 for Operations and Maintenance, Navy (OMN) funding; the Oceanographer of the Navy, N84, for Other Procurement, Navy (OPN) funding; OPNAV N87 for Commander Undersea Surveillance; OPNAV N1 for Military Personnel Navy (MPN) and Reserve Personnel Navy (RPN); and OPNAV N85 for Expeditionary Warfare re-quirements.

The Naval Oceanography Program's operational concept is "knowledge-centric" – production is centralized, service delivery is distributed in naval command and control centers and the total capabilities are brought to bear directly on Naval strategic, warfighting and safe operating challenges.

Naval Oceanography focuses its services on five warfighting capabilities--antisubmarine warfare, naval special warfare, mine warfare and countermeasures, fleet operations, and intelligence, surveillance and reconnaissance--and four strategic and enabling capabilities, maritime weather forecasting, aviation weather forecasting, navigation and charting and precise time and astrometry.

Major activities within the command currently include:

- Naval Oceanography Operations Command, Stennis Space Center, MS
- Naval Oceanographic Office, Stennis Space

Figure 3 – DOD 11. Aerographer's Mate 2nd Class Kristopher Rodriguez, writes a weather report in the meteorology and oceanography center of the aircraft carrier USS Kitty Hawk (CV 63). (US Navy Released)

Center, MS
- Fleet Numerical Meteorology and Oceanography Center, Monterey, CA
- U.S. Naval Observatory, Washington, DC
- Naval Meteorology and Oceanography Professional Development Center, Gulfport, MS
- Commander Undersea Surveillance (CUS), Dam Neck, VA

Additional subordinate commands include:

- Naval Aviation Forecast Center, Norfolk, VA and detachments
- Naval Maritime Forecast Center, Pearl Harbor, HI (with an activity in Norfolk)
- Strike Group Oceanography Teams in Norfolk, San Diego and Fallon, Nevada (with subordinate mobile environmental teams)
- Naval Special Warfare Oceanography Center in San Diego, CA (with components and detachments in Stuttgart, Germany, Norfolk and Pearl Harbor)
- Naval Oceanography ASW Centers in Yokosuka, Japan and Stennis Space Center, MS (with subordinate detachments)
- Fleet Survey Team, Stennis Space Center MS
- Naval Ice Center, Suitland, MD
- Naval Ocean Processing Facilities in Dam Neck, VA and Whidbey Island, WA (with detachments)

NAVAL OCEANOGRAPHY OPERATIONS COMMAND (NAVOCEANOPSCOM)

The NAVOCEANOPSCOM, headed by the Commander, Oceanographic Operations, serves as the principal operational organization of CNMOC and coordinates and manages efforts among field activities under the Operational Oceanography Program to optimize warfighting resources, support safe operations and enhance dominance of the battlespace through superior understanding and exploitation of the environment. The Command encompasses the nine warfighting and enabling directorates. Each director-ate determines how that directorate's services are delivered globally. Each directorate reports to a single Navy Captain who functions as Naval Oceanography's Chief Operating Officer.

The Commander, Oceanographic Operations supports the combatant commanders and national missions, U.S. interagency and international partners. The major NAVMETOCCOM production centers (NAVOCEANO, FLENUMETOCCEN, NAVOBSY) support the Commander, Oceanographic Operations.

The command's operational model is based on standardizing services for each directorate, automating everything that can be automated and coupling situational awareness and a small on-scene pres-ence, supported by a significant 24/7 reachback production capability at the major production centers.

Dangerous weather and safe navigation are the top two Fleet concerns.

Aviation Forecasting

Many environmental conditions severely impact flight operations and mission accomplishment. These include: wind speed and direction, cloud ceiling, precipitation, turbulence, visibility, icing and severe weather such as thunderstorms. An accurate forecast is often the deciding factor in mission success and for the safety of the pilot and their aircraft.

Navy Meteorologists and forecasters analyze current physical environmental conditions and use state of the art computer models to forecast atmospheric and oceanographic phenomena impacting naval flight operations.

Meteorologists are assigned to Aviation Forecasting hubs in the United States and overseas locations.

Core aviation weather services include flight route weather briefings via an internet-based flight weather briefer, severe weather warnings and advisories for Navy airfields and terminal aerodrome forecasts for Navy airfields.

Fleet Operations

The Naval Meteorology and Oceanography Command is actively engaged with Fleet forces to provide valuable physical environmental knowledge to aid warfighting decision making. Personnel are integrated with the Fleet, where they provide in situ observations, run tactical decision aids and interpret envi-ronmental data to provide decision support to Fleet commanders.

The onboard personnel work with reachback cells to analyze and forecast environmental conditions from launch point to target and to determine optimum Fleet maneuvers, ingress and egress routes, am-phibious landing points and times, flight operations, weapons load-outs and target selection.

Deploying personnel are highly trained meteorology and oceanography specialists for support planning and operations. Reachback teams work with onboard personnel to refine data, develop models, conduct forecast analyses and deliver high-quality information to Fleet commands.

Tailored Strike Group Oceanography Team (SGOT) Detachments train, work-up and deploy with carrier and expeditionary strike groups through each phase of the Fleet Readiness Training Program or Plan or whatever and deployment. Each SGOT detachment includes a team who forecast for the aircraft carriers, amphibious assault ships and other vessels making up the strike group. In addition to flight deck weather, they forecast en-route and target area METOC conditions which may vary greatly considering the tremendous reach of Naval Aviation along the world's dynamic coastlines.

Figure 3 – DOD 12. McMurdo Station, Antarctica, ice floes and treacherous weather pose challenges to Military Sealift Command's annual mission of resupplying the station. (US Navy Released)

Maritime Weather Operations

Navy meteorologists and forecasters are assigned to Maritime Forecasting Centers in Hawaii and Virginia.

Core maritime weather services include Optimum Track Ship Routing (OTSR), a weather forecast-ing service to support transoceanic voyages and coastal operations. OTSR services:

- Provide hazardous ocean and weather advisories and divert recommendations to ship Commanding Offi-cers and Masters at sea.
- Include sortie recommenda-

tions for potentially damaging weather conditions in port.
- Provide preliminary climatologic outlooks for transit and mission planning.
- Routine ship weather forecasts (WEAX) and aviation weather forecasts for ship-based helicopters (AVWX) include high wind and seas warnings and local area warnings for Fleet Concentration Areas.

The Joint Typhoon Warning Center (JTWC), established by the U.S. Pacific Command, is jointly manned with U.S. Air Force personnel. JTWC services include tropical cyclone forecasts, warnings and other products for Department of Defense warfighters operating in the Pacific and Indian Oceans. JTWC, located in Pearl Harbor, Hawaii, is an internationally recognized tropical cyclone forecasting center.

## FLEET NUMERICAL METEOROLOGY AND OCEANOGRAPHY CENTER

The Fleet Numerical Meteorology and Oceanography Center (FLENUMETOCCEN) an Echelon IV activity reporting to the Commander, Naval Meteorology and Oceanography Command, is the NOP's production center for meteorology. The center plays a significant role in the National capability for operational weather and ocean prediction through its operation of sophisticated global and regional meteorological and oceanographic models, extending from the top of the atmosphere to the bottom of the ocean. Through close collaboration with the Naval Oceanographic Office (NAVOCEANO), FLENUMETOCCEN is a key component in the Navy's operational weather and ocean prediction program. This program provides information that helps give Naval forces an asymmetric advantage in speed, access and persistence in any combat operation for which they may be called upon.

FLENUMETOCCEN is well known for its long and productive history of implementing, evaluating, operating, maintaining and improving complex Numerical Weather Prediction (NWP) system specifically to meet the requirements of the U.S. Navy. These requirements include the need for a particularly accurate representation of coastal meteorology and the air-sea heat fluxes and wind stresses required to drive the Navy's ocean models. In support of this need, FLENUMETOCCEN acquires and processes over six mil-lion observations per day -- creating one of the world's most comprehensive real-time databases of mete-orological and oceanographic observations -- for real-time fusion and assimilation into its models. In addi-tion, FLENUMETOCCEN is designated as the DOD center for global Numerical Weather Prediction. FLENUMETOCCEN uniquely satisfies the military's requirement for an operational global NWP capability based on software certified to DOD information assurance standards and operated in a secure classified environment protected from outside intrusion by DOD-certified firewalls. This requirement is driven by the importance of weather and ocean conditions on modern military operations, the need to utilize classified weather observations to guarantee the very best weather and ocean predictions in theaters of conflict, and the imperative to produce and disseminate weather and ocean products to military decision-makers without fear of interruption or compromise as a result of cyber terrorists or cyber warfare.

FLENUMETOCCEN employs four primary models: the Navy Operational Global Atmospheric Pre-diction System (NOGAPS), the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), the Geophysical Fluid Dynamics - Navy (GFDN) model, and the WaveWatch III model (WW3), along with a number of specialized models and related applications. NOGAPS is a hydrostatic, global spectral model that drives nearly all other FLENUMETOCCEN models and applications in some fashion, and forms the basis for the FLENUMETOCCEN global Ensemble Forecast System (EFS). COAMPS is a high-resolution, non-hydrostatic regional model, multiply nested within NOGAPS, that has proven to be particu-larly valuable for forecasting weather and ocean conditions in highly complex coastal areas. GFDN is a moving-nest tropical cyclone (TC) model, nested within NOGAPS, that is used to forecast TC tracks globally. WW3 is a spectral ocean wave model that is employed both globally (driven by NOGAPS) and regionally (driven by COAMPS) in support of a wide variety of naval operations. Other models support and supplement the main models with predictions of ocean thermal structure, ocean currents and other data. All of the models are configured, scheduled and operated under the central control of FLENUME-TOCCEN Operations. COAMPS, however, can also be configured, scheduled and operated remotely by users in the field as an on-demand modeling service. This is done over the Web via the FLENUMETOC-CEN Centralized Atmospheric Analysis and Prediction System (CAAPS). In general, FLENUMETOCCEN strives to treat the air-ocean environment as a fully integrated system, from the top of the atmosphere to the bottom of the ocean, placing special emphasis on the air-ocean interface.

FLENUMETOCCEN's complex and robust operational prediction capability is designed to deliver, in conjunction with NAVOCEANO, 7x24x365 support organized along the warfare areas. For example, some FLENUMETOCCEN products consist of detailed forecasts of wind stresses and heat fluxes to drive very high-resolution ocean models at NAVOCEANO that provide ocean thermal structure and currents in support of anti-submarine and mine warfare operations, or near-shore wind, sea and surf forecasts that directly support Fleet Operations through ship-to-objective maneuver. In many cases, the outputs of the FLENUMETOCCEN models feed directly into applications models, tactical decision aids and other prod-ucts that provide direct support to various weather-sensitive activities associated with the warfighting di-rectorates identified above. These include optimum path aircraft routing, optimum track ship routing, issu-ance of high-winds and high-seas warnings, hurricane/typhoon sortie decisions, covert ingress/egress of Special Operations Forces, ballistic missile targeting, cruise missile launch and targeting, radar perform-ance prediction in support of ship self defense, naval gunfire operations, understanding the threats posed by airborne nuclear/biological/chemical agents, search-and-rescue at sea, and many other activities.

FLENUMETOCCEN also provides a wide-range of meteorological and oceanographic observations and satellite imagery to complement its models and applications products. These include on-demand extracts from its global observational database, a full range of Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager products, ERS and QuikScat scatterometer wind products, a comprehensive view of tropical cyclones via the FLENUMETOCCEN TC Web Page, and vari-ous experimental satellite products fielded for evaluation in conjunction with the Naval Research Lab (e.g., satellite imagery that enhances the visualization of airborne sand and dust). FLENUMETOCCEN also hosts the USGODAE Monterey Data Server in support of the Global Ocean Data Assimilation Experiment. This system serves as a one-stop shop for meteorological and oceanographic data and model products required to support global ocean modeling R&D. It also functions as one of two Argo Global Data As-sembly Centers, hosting the complete collection of quality-controlled Argo temperature/salinity profiling float data.

Many of FLENUMETOCCEN's products are distributed to users over the Web via the PC-based METCAST system, and subsequently displayed and manipulated on the user's PC with the Joint METOC Viewer (JMV) software. This includes all standard meteorological and oceanographic fields, synoptic ob-servations, and satellite imagery. For those who require only graphical display of model-predicted mete-orological or oceanographic fields, FLENUMETOCCEN provides a Web-based capability called WxMap (i.e., "Weather Map"). WxMap, requiring only a Web browser for access, allows the user to select and quickly display predicted meteorological and oceanographic fields for any user-defined geographical area.

All of FLENUMETOCCEN's production capabilities are fielded on a collection of computer hard-ware and software designated as the Primary Oceanographic Prediction System (POPS). POPS is or-ganized into two subsystems: the Analysis and Modeling Subsystem (AMS) and the Applications, Trans-actions, and Observations Subsystem (ATOS). AMS is a cluster of SGI and IBM supercomputers on which the major NWP models run. ATOS is a large suite of IBM Linux clusters that ingests, decodes and quality-controls data; does satellite data processing; hosts many of the applications models and products mentioned above; and supports data distribution via a services oriented architecture and Web portal. Note that FLENUMETOCCEN also hosts a DOD High Performance Computing Modernization

Program (HPCMP) Distributed Center, which are integrated closely with POPS.

In addition to its primary role of focused support to the warfighter, FLENUMETOCCEN also plays a key role in the U.S. national program for weather prediction. In this regard, FLENUMETOCCEN's tropical cyclone track predictions, widely recognized as among the best in the world, have proven to be especially valuable, with the National Hurricane Center (NHC) relying on them heavily.

FLENUMETOCCEN benefits greatly from collocation with its supporting R&D activity, the Marine Meteorology Division of the Naval Research Laboratory (NRL/MRY). NRL/MRY is a world-class research organization, with focus on weather-related support to warfighting. FLENUMETOCCEN and NRL/MRY share space, data, software and computer systems, and together with the nearby Naval Postgraduate School represent one of the largest concentrations of weather-related intellectual capital in the nation. Collocation and close cooperation between research and operations, such as exists between NRL/MRY and FLENUMETOCCEN, is the optimum arrangement for transitioning R&D quickly and cost-effectively into new and improved operational weather prediction capabilities.

## NAVAL OCEANOGRAPHIC OFFICE

The Naval Oceanographic Office is the NOP's production center for oceanography.

Since atmospheric conditions are inherently

Figure 3 – DOD 13. The Nassau Expeditionary Strike Group transits the Atlantic Ocean. (US Navy Released)


Figure 3 – DOD 14. Aviation Warfare Systems Operator 2nd Class Anthony Chavez, works with a soldier from the Armed forces of the Philippines to move relief supplies to a school on the Panay Island. (US Navy Released)

coupled to oceanographic conditions, the Navy's pro-gram in meteorology is closely linked with oceanography , which is the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO primary responsibilities in-clude the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO runs and disseminates products from the world's first operational global ocean model, NRL Layered Ocean Model (NLOM), as well as a number of regional and coastal cir-culation and wave models. NAVOCEANO also runs the Polar Ice Prediction System (PIPS) ice model and provides the output to the National Ice Center for product generation. A key ingredient to ocean model performance is real-time data for assimilation and evaluation. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is nationally recognized for satellite-derived sea-surface temperature and satellite altimeter-derived sea surface topography and wave height. NAVO-CEANO's global sea surface temperature are critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO houses a DOD Major Shared Resource center, enabling transition of the latest research and development models on the most scaleable, supercomputing architecture and facilitating transition from R&D to operational use.

Figure 3 – DOD 15. Marines from India Battery, Battalion Landing Team 2/5, 15th Marine Expeditionary Unit, fire their M777 Howitzer while deployed to Buehring, Kuwait. (USMC Released)

## UNITED STATES NAVAL OBSERVATORY

The U.S. Naval Observatory, in Washington, D.C., is the production center for precise time and as-trometry. It is one of the oldest scientific agencies in the country. Established in 1830 as the Depot of Charts and Instruments, the U.S. Naval Observatory today is the preeminent authority in the areas of Pre-cise Time and Astrometry and distributes Earth Orientation parameters and other astronomical data re-quired for accurate navigation and fundamental astronomy.

The U.S. Naval Observatory serves as the official source of time for the Department of Defense and the standard of time for the United States. The atomic clock timescale of the Observatory is based on an ensemble of cesium-beam frequency standards and hydrogen masers.

The U.S. Naval Observatory performs an essential scientific role for the United States, the Navy and the Department of Defense. Its mission includes determining the positions and motions of the Earth, Sun, Moon, planets, starts and other celestial objects, providing astronomical data; determining precise time; measuring the Earth's rotation; and maintaining the Master Clock for the United States. Observatory astronomers formulate the theories and conduct the relevant research necessary to improve these mission goals. This astronomical and timing data, essential for accurate navigation and the support of communica-tion on Earth and in space, is vital to the Navy and Department of Defense. It is also used extensively by other government agencies and the public at large.

### EDUCATION/TRAINING

Navy Officer (meteorologists/oceanographers) are all university graduates in meteorology, ocean-ography or other earth sciences, with most attaining dual meteorology and oceanography advanced graduate degrees.

Enlisted forecaster and/or briefers are trained in meteorological analysis and forecasting at military schools. Enlisted observers receive training at military schools.

The enlisted Aerographer's "A" (observer) and "C" (forecaster) schools are located at the Naval Technical Training Unit collocated with Air Force and Marine weather training at Keesler Air Force Base, MS.

Ongoing professional development for both officer and enlisted personnel is offered through the Naval Meteorology and Oceanography Professional Development Center in Gulfport, MS (with Pacific and Atlantic detachments). The center offers directorate training as well as training on oceanographic knowl-edge continuum.

### THE FUTURE

The central objective for the Naval Oceanography Program's future capability is a three-tiered con-struct designed to bring the forecast battlespace into operational decision making. It hinges on high reso-lution modeling and will require extensive sampling and continuous validation. All three tiers, each encom-passing a separate knowledge set, will be developed simultaneously.

Tier 1, the "environment layer" will consist of developing and using the sampling methods given the observed and forecast ocean/atmosphere system and the desired knowledge to be gained. Littoral Bat-tlespace Sensing Fusion & Integration is the baseline Program of Record for acquiring Navy-unique data and sensors critical to model initialization, verification, validation, skill improvement and confidence. In this tier, focus will also be placed on

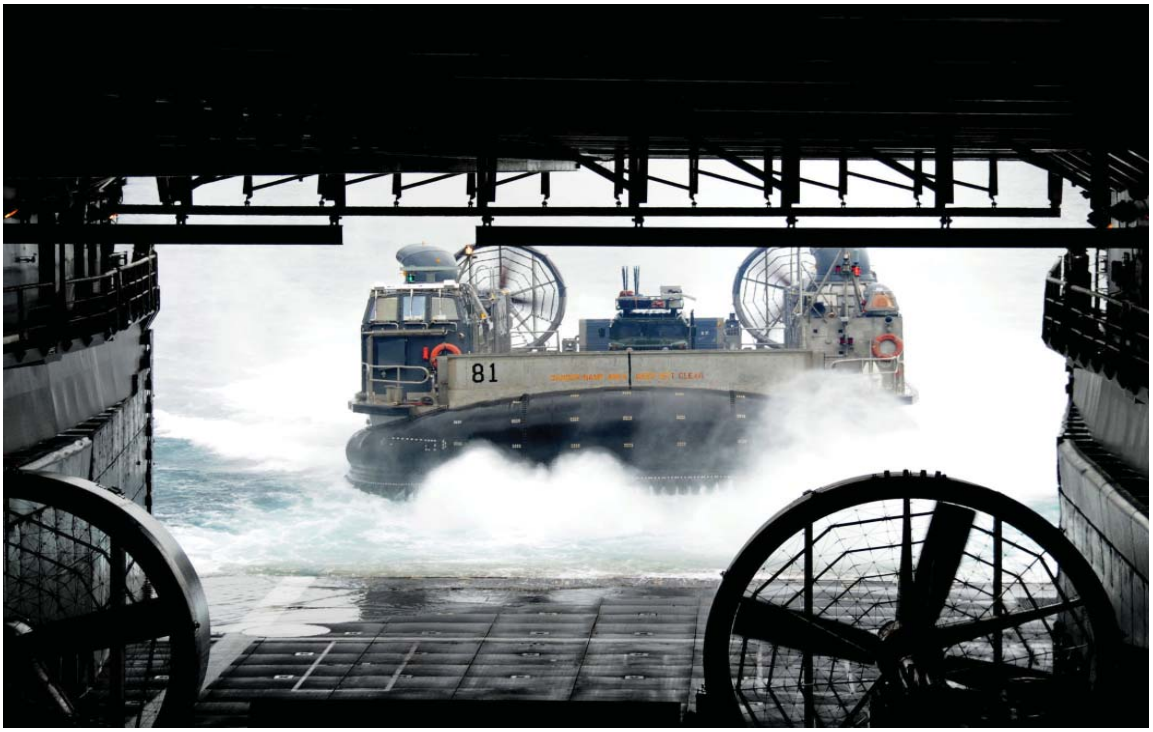


Figure 3 – DOD 16. Landing craft air-cushioned (LCAC) 81, assigned to the “Swift Intruders” of Assault Craft Unit (ACU) 5 follows another LCAC into the well deck of the amphibious dock landing ship USS Harpers Ferry (LSD 49). (US Navy Released)

improving modeling capability in an air/ocean environment at all scales, aligned with a National approach in areas where leverage is possible.

Tier 2, the “performance layer” revolves around transforming understanding of the air-ocean envi-ronment into knowledge of that environment will impact sensors, platforms and people and communicat-ing inherent opportunities and constraints.

Tier 3, “the decision layer,” applications will quantify strategic and operational risks, provide asset allocation recommendations at the operational level and sensor settings and predictions at the tactical level. As much of this information as possible will be provided via the Web and tailored “push” products.

Together the three “tiers” will deliver time-responsive, “on demand” sensing and modeling and pre-diction of critical ocean parameters on strategic, operational and tactical timelines with tightly coupled warfighting applications.

PROGRAM ALIGNMENT

The Naval Oceanography Program is changing focus from an acquisition-based program to “in stride” technology transition that rapidly transitions R&D and influences the Navy’s S&T investments. Emerging R&D technologies will be tested in computational and operational environments and transitioned after an appropriate collaborative period.

CONCLUSION

The Naval Oceanography Program has reinvented itself into a program that emphasizes the Navy’s interests – and will evolve as the Navy’s future challenges evolve. Ultimately, it delivers an operational Na-val Oceanography Program (aligned vertically with the S&T and R&D communities) that protects the Fleet, helps the Nation shape the battlespace and maximizes warfighting capability.

## UNITED STATES MARINE CORPS (USMC)

The mission of the Marine Corps METOC Service is to provide meteorological, oceanographic, and space environmental information, products, and services required to support Marine Corps and other military operations. The Marine Corps METOC support infrastructure is designed to readily deploy and operate in austere expeditionary environments. It is capable of providing sustained, comprehensive, and relevant METOC support to all elements of a Marine Air Ground Task Force (MAGTF), as well as bases and stations of the supporting establishment.

ORGANIZATION

The Deputy Commandant for Aviation, Headquarters U.S. Marine Corps (Code ASL-37), is the re-sponsible office for Marine Corps METOC requirements and support. The Marine Corps METOC organi-zation consists of two operational chains of command, one for supporting establishment METOC units, and the other for the Fleet Marine Force (FMF).

Supporting establishment METOC units are located worldwide at Marine Corp Air Stations (MCAS) and Facilities (MCAF). These activities are manned and equipped to provide direct aviation METOC support and services to host and tenant units at seven major air stations in the continental United States, one in Hawaii, and two in Japan.

Within the FMF, Marines deploy as scalable, tailored, combined-arms teams known as MAGTFs. There are three sizes of MAGTFs. They are the Marine Expeditionary Unit (MEU), Marine Expeditionary Brigade (MEB), and Marine Expeditionary Force (MEF) with the latter being the largest. Additionally, Spe-cial Purpose MAGTFs may be formed to support operationally unique situations and/or requirements. All MAGTFs, regardless of size, share four organizational elements that vary in size and composition accord-ing to the mission: Command Element (CE), Ground Combat Element (GCE), Aviation Combat Element (ACE), and Combat Service Support Element (CSSE).

FMF METOC activities are organized, trained, and equipped to provide tailored support products and services to all combat elements of the MAGTF. METOC support is focused towards impacts on expeditionary maneuver warfare operations, particularly operational maneuver from the Sea. FMF METOC activities are fully interoperable within joint force operations as part of a Service or functional component command. When directed to stand-up as part of a Joint Task Force headquarters (JTF HQ), they are capable of planning, coordinating, and leading joint METOC operations. Marine METOC forces can rapidly transition from pre-crisis state to full operational capability in a distant theater to provide on-scene support to MAGTF, combined, joint, allied, and coalition operations and other military operations as may be di-rected. FMF METOC assets are permanently assigned to MEF headquarters, intelligence battalions, Ma-rine Wing Support Group (MWSG), and Marine Wing Support Squadron (MWSS). There are three MEFs strategically positioned for global response. I MEF, based in southern California and III MEF, forward based in Okinawa, Mainland Japan, and Hawaii fall under the control of the Commander, Marine Forces Pacific. II MEF, located at bases in North and South Carolina, falls under the Commander Marine Forces Command. MEF METOC personnel serve as special staff to the commanding general and are under the direction and cognizance of the intelligence division (G-2).

Figure 3 – DOD 17. The Meteorological Mobile Facility-Replacement Next Generation Vehicle (USMC Released)

The three intelligence battalions in the Marine Corps are co-located with respective MEF headquarters. These battalions directly support the MEF G-2 and serve as MAGTF intelligence centers during operations. METOC is a vital part of the intelligence estimate and is an essential element that supports the Marine Corps Rapid Response Planning Process. METOC personnel assigned to these commands pro-vide expertise, products, and services that directly support the intelligence preparation of the battle-space (IPB) process by helping intelligence analysts to effectively evaluate, integrate, and synchronize METOC effects for both enemy and friendly courses of action.

The Marine Aircraft Wing (MAW) conduct the complete range of air operations in support of the MEF, to include anti-air warfare, offensive air support, assault support, aerial reconnaissance, electronic warfare, and control of aircraft and missiles. The MAW serves as the principle headquarters for the ACE. Most of the MAGTF's METOC support assets reside within the MAW, specifically at the MWSG and its subordinate MWSS. These assets are organized, structured, and capable of supporting a variety of MAGTF and ACE-specific operations as defined by the size, scope, and mission requirements. Dedicated METOC support is available for all MAGTF elements from within the MAW/ACE.

## METOC SUPPORT CAPABILITIES

### Meteorological Mobile Facility-Replacement (MetMF(R))

The highest level of METOC support to the MAGTF and ACE-specific operations is the deployment of the MetMF(R). The MetMF(R) provides a METOC support capability similar to that found in garrison METOC facilities. The MetMF(R) is normally employed as part of MWSS to a forward operating base and is the only realistic option for large-scale MAGTF operations. Once established ashore, the MWSS may detach small METOC support teams with portable ancillary equipment to a forward base in support of ACE units that are separated from the main airbase. This redeployment also provides the MetMF(R) with a forward data collection capability that significantly enhances METOC situational awareness and overall support efforts to the entire MAGTF. With appropriate Service personnel augmentation, the MetMF(R) is also capable of serving as host for an in theater Joint METOC Coordination Cell (JMCC) during joint operations and exercises.
The METMF(R) NextGen is a mobile system that will provide tactical meteorological support to the Marine Air Ground Task Force   This system will replace the legacy METMF(R) with current and emerging state-of-the-art technologies offering a smaller overall size and increased mobility. These advancements will significantly enhance the meteorological capabilities of the Marine Corps Expeditionary Forces.

### METOC Support Team (MST)

The MST is task organized and equipped to provide a limited level of METOC support to combat elements other than the ACE (e.g., CE, GCE, and CSSE) and are assigned in support of MEU operations. It is capable of rapidly deploying as part of a first-in level of METOC support response to a crisis and can be easily integrated into an Air Contingency MAGTF. Additionally, the MST can be assigned to augment a JMCC during joint operations. Each MWSS within the MAW is structured and organized to provide one MST that consist of one METOC officer, two forecasters, and two observers. When deployed, the MST will normally be assigned to the intelligence division/section (G/S-2) of the supported combat element or MEU. The MST deploys with rugged, ancillary environmental collection and data processing equipment. During operations they organically collect METOC products, data, and information from the nearest de-ployed MetMF(R), Navy METOC OA Division afloat, host nation, or other METOC support organizations and agencies to satisfy METOC information requirements.

## SPECIALIZED METOC SUPPORT

The Marine Corps' Chemical Biological Incident Response Force was established in 1996, as a result of Presidential Decision Directive 39 to manage the consequences of NBC materials or weapons used by terrorists. This national-level asset is part of the reactivated 4th Marine Expeditionary Brigade - Anti-Terrorism located at Indian Head, MD. It is comprised of specially trained and equipped Navy, Marine, and civilian personnel who can rapidly be forward deployed and/or respond to a credible threat of a CBRNE incident in order to assist local, state, or Federal agencies and designated unified combatant commanders in the conduct of consequence management operations. Within the S-2, permanently as-signed METOC forecasters provide specialized NBC dispersion forecast products and services that aid mission accomplishment of this organization.

The U.S. Army is undergoing a historical transformation from a division-centered Army, to a smaller, brigade-based Army. This transformation will require an adjustment on how weather support will be provided to the new modular Army. The Army and Air Force are discussing the possibility of weather person-nel being pooled at designated Army locations to provide a force pool of personnel ready to accompany deploying Army forces. These force pools will rely more on "reach back" capabilities to obtain pertinent meteorological data. The Army and Air Force are working together to determine the optimal weather team sizing, equipment, and communications capabilities required to support the new modular Army forces.

## OPERATIONAL EQUIPMENT AND SUPPORT MISSIONS

Although it is transforming to a modular force, the existing weather support structure within the U.S. Army is a mix of Army and USAF personnel and equipment according to Army-Air Force agreement (Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, Weather Support for the U.S. Army, 30 June 1996). This joint regulation describes the Service responsibilities and those of Army Commands and Army Service Component Commands (ASCC) within the Army for providing weather support. The U.S. Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers. Air Force (AF) Major Commands (MAJCOMs) provide op-erational weather services to war fighting ASCCs in combat, contingencies, and peacetime training. U.S. Army Forces Command (FORSCOM), U.S. Army Europe (USAREUR), U.S. Army Pacific (USARPAC), U.S. Army Special Operations Command (USASOC), Eighth U.S. Army (EUSA), and U.S. 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 ASCC. During peacetime training and activation, the Air National Guard (ANG) provides AF operational weather support to the U.S. Army Reserve (USAR) and the Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies, the ANG may augment the active Army as weather personnel.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDT&E) ranges, centers, and other research facilities using the Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and U.S. Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is established under Army Test and Evaluation Command. SMDC provides weather support to the Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF weather personnel for tactical operations. The Distributed Common Ground System – Army (DCGS-A) provides the U.S. Army's tactical weather communication, intelligence, and information system providing digital weather support to the commanders and staffs of tactical units, from Echelons Above Corps (EAC) to aviation bat-talions.

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 observa-tions at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET Crews in the Active Army (AA) 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 Multipurpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire (Figure 18), to USAF weather personnel, and to the

Figure 3-DOD-18. Accurate wind profiles are essential for the Artillery to engage their targets. (US Army Released)

Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations. The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK develops requirement documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff, G-2, is responsible for Army weather support policy. The Office of the Deputy Chief of Staff, G-3, is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements.

ARMY OPERATIONAL SUPPORT PROVIDED BY THE AIR FORCE

Under AR 115-10/AFJI 15-157, the AF is provides the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison Active Army and reserve component support requirements. Army support manpower requirements are sourced from AF active, re-serve, and ANG weather personnel. While direct support of the Field Artillery remains an Army responsi-bility, and is supported by Army ARTYMET teams, AF Weather personnel provide supplemental informa-tion to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the war fighting Army Commands and ASCCs at theater, corps, division, armored cavalry regiments, and separate brigades to provide direct, on-site weather support. Air Force Special Operations Command (AFSOC) Special Operations Weather Teams (SOWTs) conduct weather operations for USASOC and are primarily funded by USSOCOM. AF operational weather squadrons (OWSs) and post-level weather organizations provide garrison and tactical weather warning, observing, forecasting, special support,

Figure 3-DOD-19. Reliable wind forecasts are necessary to ensure safety during flight operations. (US Army Released)

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. Per Army-AF agreement, the AF is responsible for in-stallation, operation, and maintenance of standard AF meteorological and observing equipment at Army Airfields. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army's IMETS is fielded for these purposes and is operated by AF personnel. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorologi-cal functions within IMETS. IMETS uses AF meteorological software, but IMETS is hosted on an Army vehicle, uses Army tactical communications and Army weather effects software. IMETS baseline software is hosted on Army Common Hardware and is Defense Information Infrastructure Common Operating Envi-ronment (DIICOE) and Joint Technical Architecture - Army (JTA-A) compliant. The Army provides other tactical equipment to AF Personnel through an Army Table of Organizations and Equipment (TOE). The following paragraphs describe weather activities within Army Commands and Army Service Component Commands.

U.S. ARMY FORCES COMMAND (FORSCOM)

Weather support to the U.S. Army Forces Command is diverse and demanding. FORSCOM, the Army's largest major command, requires and uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observa-tions for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations. FORSCOM consists of more than 750,000 Active Army (AA), U.S. Army Reserve (USAR) and Army National Guard (ARNG) soldiers. These soldiers account for more than 80 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 component of FORSCOM has nearly 200,000 soldiers. Third U.S. Army is the Army component of U.S. Central Command (USCENTCOM), which is the Joint command responsible for Southwest Asia (SWA), the Persian Gulf, and the Horn of Af-rica. U.S. Army South (USARSO) serves as the Army component to U.S. Southern Command (US-SOUTHCOM). USARSO relocated from Fort Buchanan, Puerto Rico, to Fort Sam Houston, Texas, in 2003 and became a FORSCOM major subordinate command October 1st, 2003. FORSCOM also commands three Army Corps: I Corps at Fort Lewis, Washington, 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. Two Continental U.S. Armies (CONUSAs), First U.S. Army and Fifth U.S. Army, are respon-sible for training, mobilization, and deployment support to Reserve Component units in FORSCOM. An-other major subordinate command to FORSCOM, the U.S. Army Reserve Command (USARC), com-mands all U.S. Army Reserve units in the continental United States except those assigned to Special Op-erations Command. FORSCOM's Army Reserve strength stands at approximately 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, transporta-tion, maintenance and supply.

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

Weather support to FORSCOM's AA units comes from dedicated AF weather personnel aligned under three Air Support Operations Groups (ASOGs) within Air Combat Command (ACC): 1 ASOG at Fort Lewis, Washington; 3 ASOG at Fort Hood, Texas; and 18 ASOG at Pope AFB, North Carolina. A weather squadron under each ASOG supports the Corps. Each Army division normally has dedicated AF personnel aligned under an Air

Support Operations Squadron (ASOS) or one of the weather squadrons, at their respective installations. Corps and division weather personnel are authorized 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. Currently, there are nearly 350 authorizations supporting various echelons across FORSCOM. These personnel, enabled by an operational weather squadron, provide garrison and tactical weather warning, observing, mission execution forecast, special support, and SWO services during peacetime, combat, contingency, exercise, or armistice operations.

ACC weather organizations provide direct, on-site support at 11 major Army 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 AF weather personnel with a Modified Table of Organization and Equipment (MTOE) and operating funds (expendables, maintenance, etc.). ARTYMET requirements in FORSCOM increased from 17 to 20 sections in FY 2005 due to modularity. These 6-person sections, comprised of Army weather personnel, collect upper air observations for direct use by field artillery units..

The New Tactical Forecast System (N-TFS) is the primary in-garrison and tactical weather equipment for receiving graphics and alphanumeric data. Data is received via the Very Small Aperture Terminal (VSAT), Tactical VSAT (T-VSAT), Non-Secure Internet Protocol Router Network, and Secure Internet Pro-tocol Router Network. Nineteen IMETS and 15 IMETS-Lights, developed by the Army Research Labora-tory, have been fielded within FORSCOM. FORSCOM has also fielded commercial Automated Weather Observing Systems at Yakima Training Center Washington, Fort Campbell, Kentucky, and Georgetown Bahamas.

TRAINING AND DOCTRINE COMMAND (TRADOC)

Headquarters, TRADOC is responsible for development and management of Army weather training programs, weather support doctrine (concepts and field manuals), and the establishment of Army re-quirement documents for tactical weather support. Key mission areas for the next few years will be to as-sist the AF to develop and implement a new weather support concept to meet the needs of the Army's Modular Force including Brigade Combat Teams and Future Combats Systems; to update weather sup-port doctrine, policy, organization, concepts, and tactics, techniques, and procedures; to ensure weather effects to Army operations are documented and communicated to soldiers and AF weather support per-sonnel, and to ensure Army weather support processes and procedures are trained across the TRADOC schoolhouses.

The Integrated Meteorological System (IMETS) is a program of record that continues as the state-of-the-art Army meteorological decision-aid support system. Over the next few years some of its capabili-ties will be consolidated into the Air Force's Joint Environmental Toolkit (JET) program. The Army will 1) retain research and development efforts related to Army-specific weather support challenges, 2) be re-sponsible for integrating JET into DCGS-A weather services and interfacing JET with Army command and control systems, and 3) will be responsible for fielding IMETS/JET software capabilities on common Army hardware systems. In FY08, the IMETS Program Office moved under the Program Executive Office - Intel-ligence, Electronic Warfare & Sensors (PEO-IEW&S) as part of the Distributed Common Ground System-Army (DCGS-A) program. Initial JET fielding (Terrain/Weather V4.0 Spin-Out) is programmed to begin in 1QFY 2010.

The U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH) is the functional proponent for Army tactical weather support. USAIC&FH represents the Army warfighter by collecting weather support requirements and developing solutions to satisfy those requirements when they are the responsibility of the Army. The key system that provides weather support to the Army is IMETS, which is fielded by the Army and operated by AF weather personnel. The USAIC&FH Weather Team assists the IMETS program by advising the Army Research Lab, USAIC&FH, DAMI-OPS, and AF/A3O-W on Army weather support shortfalls and issues. The USAIC&FH Weather Team provides instruction on weather support techniques and weather effects to Army operations to Army Military Intelligence personnel as well as AF weather per-sonnel supporting the Army. The USAIC&FH Weather Team consists of two active duty AF weather per-sonnel, one civilian contractor that manages the Battlefield Weather Course (BWC), and one Department of the Army Civilian that serves as the assistant TRADOC Capabilities Manager (TCM) for IMETS. The USAIC&FH Weather Team recently drafted an Army Weather Functional Area Analysis for Battlespace Weather Sensing and will continue associated work on weather inputs to the Intelligence, Surveillance and Reconnaissance Concept Capabilities Plan. The team has also authored a plan with HQ TRADOC to create an Army Weather Proponent office (AWPO) at Fort Huachuca. The purpose of this AWPO would be to oversee Army weather concerns, serve as the Army's focal point for weather requirements and will lead the Army's functional efforts in guiding concepts and capabilities development, experimenta-tion, DOTMLPF, and requirements determination. This effort will help coordinate and de-conflict all Army weather initiatives and represent Army Intelligence in all weather program and development issues. This initiative includes the hire of a Department of the Army Civilian to serve as AWPO Chief. The TCM for IMETS coordinates with DCGS-A to ensure the highest level of integration of IMETS into the DCGS-A family of systems. The TCM recently participated in the DCGS-A Fusion Working Group and provided DCGS-A an evaluation of IMETS ability to satisfy the DCGS-A requirements.

The AF SWO at the Army's Combined Arms Center (CAC) is the primary overseer of the Tables of Organization and Equipment (TOE) for AF weather teams supporting Army operations. The CAC SWO is the AF point of contact for implementing TOE structure changes for support to Modular Forces in the Transformed Army. The CAC SWO also arranges for or provides environmental data, concepts of opera-tion, and weather subject matter expertise for programs, projects, documents, and studies conducted by 1) the TRADOC System Manager - Army Battle Command System, 2) the Battle Command Battle Lab-Leavenworth, 3) the Center for Army Lessons Learned, 4) the Combined Arms Doctrine Directorate, 5) the TRADOC Assistant Deputy Chief of Staff for Intelligence –Threats, the Foreign Military Studies Office, and 6) the TRADOC Analysis Center-Leavenworth. Other key CAC SWO tasks are to develop weather/weather effects scripts and climatology packages to support modeling and simulation efforts of the Battle Command Training Program (BCTP) and the National Simulation Center, to make available Army weather support instruction at the Command and General Staff College (CGSC), to provide climate expertise to all units assigned or attached to Fort Leavenworth and to be the Staff Weather Officer to the U.S. Army Aviation Warfighting Center (USAAWC) at Fort Rucker, AL. point of contact for weather sup-port.

The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK is the proponent for upper air mete-orological support to the Army. The AN/TMQ-41 Meteorological Measuring Set (MMS) and AN/TMQ-52A Meteorological Measuring Set-Profiler (MMS-P) are utilized to conduct surface and upper air obser-vations. The MMS and MMS-P provides weather data to the Field Artillery Tactical Data System for ballis-tic calculations; to USAF weather personnel for weather forecasting; and to the Chemical Officer for ob-scurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations. Efforts are ongoing to ensure these surface and upper air observations are sent back to military weather centrals where they can be ingested in to our newest numerical meteorological analysis and forecasting models. Active unit's MMSs will eventually be replaced by the AN/TMQ-52A Meteorological Measuring Set Profiler (MMS-P). The MMS-P is currently being fielded and is scheduled for completion of fielding by FY11. The MMS-P is a suite of meteorological sensors and associated software/models which will provide the Field Artillery with current and/or expected weather conditions at a point where the weapon munitions is expected to engage a target (Target Area Met). Currently, both the MMS and MMS-P are trained to all Advanced Indi-vidual Training soldiers attending the Field Artillery Meteorology Course.

The U.S. Army Aviation Warfighting Center (USAAWC) at Fort Rucker, AL incorporates weather instruction and procedures into rotary-wing training programs in their mission areas. The center is the proponent for all Army Aviation including Unmanned Aerial Vehicle Systems (UAVS). The Center has re-quirements 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.

Back in FY04, Air Combat Command (ACC) contracted day-to-day operational weather support to aviation operations at Fort Rucker (Cairns Army Airfield, Troy Municipal Airport, and Andalusia Municipal Airport) to 3D Research Corporation (3DRC). ACC, through the same contract with 3DRC, also provides garrison airfield weather services (observing and/or forecasting) at Fort Belvoir, Fort Benning, Fort Knox, Fort Leonard Wood, Fort Huachuca, and Fort Sill. The current 3DRC contract ends in Aug 08, and will then be re-bid to ensure there is no lapse in services.

Eighth U.S. Army

The Eighth U.S. Army uses Army resources to measure surface and upper air meteorological data for artillery meteorology (ARTYMET) support. Second Infantry Division's (2 ID) First Heavy Brigade Com-bat Team (1 HBCT) uses the newly field AN/TMQ-52 Profiler System, while 2 ID's 210th Fires BDE uses the legacy AN/TMQ-41 Meteorological Measuring Set to collect upper air data for direct use by field artil-lery units.

Figure 3-DOD-20. Meteorological Measuring Set – Profiler (MMS-P) obtains upper level wind data for artillery fires. (US Army Released)

Air Force weather personnel assigned to the 607th Weather Squadron (607 WS) provide operational weather support to Eighth Army units. The 607 WS provides garrison and tactical weather observ-ing, advisories, mission execution forecasts and staff weather support during armistice operations, exer-cises and contingencies. These personnel use knowledge of Army missions to prepare theater-scale and site-specific weather forecasts essential to resource protection, operational planning and execution of combat operations. The 607 WS has personnel at five installations to provide direct weather support to HQ Eighth Army, HQ 2 ID and the 2nd Combat Aviation Brigade (2 CAB). In FY08, the 607 WS has 65 assigned weather personnel to support the Army mission. IAW AR 115-10/AFJI 15-157, the Eighth Army provides garrison facilities, tactical equipment (MTOE and CTA) and an operating budget.

United States Army Europe

U.S. Army Europe (USAREUR) and 7th Army (7A) require and use Army resources to provide 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.

The Air Force's 7th Weather Squadron (7WS) 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 U.S. 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. Weather teams located at V Corps and its aviation assets, 1st Armored Division and its aviation brigade, Southern European Task Force, and 7th Army Training Command, as well as

7WS sup-porting 7th Army, evaluate and tailor these forecast products to enhance 7A Staff situational awareness and produce mission execution forecasts when needed.

The 7WS mission, with its 5 detachments and operating locations, provides weather operations packages to conform to the Army's garrison and war operations. Additionally, 7WS conducts weather operations and planning to meet future Army transformation and modularity initiatives. 7WS will provide or arrange deploying weather force structure to match missions USAREUR, or its subordinate elements, is called upon to execute. 7WS will tailor the permanently assigned weather force to meet requirements of the 7A structure and utilize "reachback" capabilities to the maximum extent possible to minimize the fielded footprint without compromising weather operations.

Three Integrated Meteorological Systems (IMETS) and five IMETS Lights are fielded within USAREUR (V Corps, two divisions and their aviation brigades, and two separate brigades). IMETS is geared to interface as a module of the Army Battlespace Control System to inject decision-quality weather products into the common operating picture for Army commanders.

USAREUR provides supporting USAF weather teams with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four artil-lery 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 obser-vations at forward areas in the battlespace. USAREUR G2 funds purchases of handheld weather sensors for use in FALOP training and equipping Army teams to provide limited weather data at Forward Operat-ing Bases and Forward Arming and Refueling Points. This data provides critical information that benefits flight safety as well as the theater weather sensing strategy without having to forward deploy more people to austere locations.

7WS also provides combat skills training to weather forecasters to increase their ability to be assets in combat, should the need arise. Some training and equipment are supplied by Joint Multinational Training Center HHC.

<u>U.S. Army Special Operations Command (USASOC)</u>

Routinely deployed in over three dozen countries, USASOC's forces have demanding missions spanning the globe and all levels of warfare. Special Operations Forces (SOF) missions are often carefully managed, high-risk scenarios operating at the edge of equipment capabilities, frequently at night and in adverse weather; these mission profiles routinely create great demands for precise weather information. SOF meteorological and oceanographic (METOC) operations with USASOC forces enable commanders to improve efficiency, effectiveness and safety of operations. Air Force Special Operations Command (AFSOC) Special Operations Weather Teams (SOWTs) and Air National Guard (ANG) weather person-nel provide direct support to USASOC units and are assigned to AFSOC's 10th Combat Weather Squadron (CWS); 320th Special Tactics Squadron (STS); and 321st STS. ANG personnel providing di-rect support to USASOC when activated are assigned to the 107th Weather Flight (MIANG), 146th Weather Flight (PAANG), and the 181st Weather Flight (TXANG). These SOWTs employ specialized AFSOC-provided tactical METOC kits to conduct environmental reconnaissance and provide METOC observations from data-sparse areas in permissive and uncertain environments for planning and executing U.S. military operations. At the deployed team level, 10th CWS SOWTs collect weather data that are used by SOF commanders and staffs and forwarded to strategic METOC centers to improve meteoro-logical models & forecasts. Additionally, SOWTs operate with the U.S. Army Special Forces Command's seven Special Forces Groups (SFG); the 75th Ranger Regiment; the 160th Special Operations Aviation Regiment; all SFG and regimental subordinate battalions, and Psychological Operations Groups. AFSOC SOWTs provide the DOD's sole source for high-fidelity METOC environmental data collection from aus-tere, denied, hostile, or semi-permissive areas of the battlespace. In addition, full-spectrum METOC opera-tions include: climatology, solar/lunar illumination and geometry analyses and atmospheric effects studies; feasibility analyses, courses of action and mission impact assessments; surface, upper-air and tactical ra-dar observations; weather watch/warnings; highly-resolved mission execution forecasts that demand fully-integrated and highly-qualified SOF METOC forces, including flight weather briefings and drop/landing zone forecasts; training ARSOF and host nation and indigenous forces on conducting limited METOC observations; and foreign internal defense analyses, surveys, and training.

USASOC plans and expends resources for some operational and administrative support to SOWTs operating with USASOC components. USASOC provides funding for office and deployable automation systems and connectivity to local networks; operations and maintenance/sustainment to sup-port USASOC requirements. Additionally, USASOC provides for some tactical items such as NBC and some communications equipment; electrical power, vehicles, life support equipment necessary for ac-complishing AFSOC's USASOC weather operations; and maintenance and supplies for USASOC-provided equipment. USASOC also provides funding for facilities, telephones, office space, and real property to house supporting special operations weather units, as well as secure storage of required equipment.

Figure 3-DOD-21. Soldiers and equipment are constantly exposed to the elements, as evidenced by this dust covered HMMWV. US Army photo by Sgt. Igor Paustovski. (US Army Released)

USASOC and AFSOC are cooperating to integrate the Joint Environmental Toolkit (JET) into the DCGS-A and suite of SOF operational capabilities. Two AFSOC meteorological liaison staff from the HQ AFSOC/A3W (Operations Weather Division) are located at HQ USASOC to coordinate AFSOC-USASOC METOC operations, logistics, and related requirements.

United States Army Pacific (USARPAC)

U.S. Army Pacific (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 Integrated Meteorological System (IMETS) and New Tactical Forecast System (NTFS) have been fielded within USARPAC as the primary meteorological equipment for deployed operations. The IMETS and NTFS receive data via Army-provided reachback NIPRNET and SIPRNET conduits.

The 17th Operational Weather Squadron (17 OWS) at Hickam AFB, HI, provides HQ USARPAC ASCC with garrison and tactical weather warnings, forecasts, special support, and Dedicated Support (DS) Staff Weather Office (SWO) services. Additional AF personnel provide DS weather support to the 25th ID (L), 25th CAB, and the 1-25 SBCT. USAF also provides weather support, though not in a DS role, to U.S. Army Japan (USARJ), U.S. Army Hawaii (USARHAW), 4-25 IBCT, USARPAC's Early Entry Command Post (EECP), and U.S. Army Alaska

(USARAK). DS AF personnel deploy with their supported operational organizations, providing tailored battlefield observations and forecasts. Weather reengineer-ing has reduced the requirement for forward-deployed weather personnel, instead leveraging IMETS and other recently fielded technology for reachback capability. 17 OWS provides regional weather support, allowing forward-deployed AF personnel to focus on specific area and target forecasts.

There are three subordinate commands within USARPAC: U.S. Army, Hawaii (USARHAW), U.S. Army, Alaska (USARAK), and U.S. Army, Japan (USARJ).

The 17 OWS provides tactical- and operational-level forecast products for the PACOM AORs, to include all USARJ, Korean Theater of Operations, and Alaska. This includes specific resource protection support (i.e. weather advisories, warnings, and watches), as well as Terminal Aerodrome Forecasts for se-lected units.

The 5th Air Force (5 AF) Liaison serves as USFJ's Staff Weather Officer (SWO), and also serves as the USARJ SWO. Day-to-day support for Camp Zama, Japan is provided by an Operating Location (OL) under the AF CWT assigned to the 374th Operational Support Squadron at Yokota AB. The OL on-site at Camp Zama provides weather observation services and produces mission execution forecasts ISO support aviation operations.

The 17OWS provides strategic and theater level weather support and services to all DOD units stationed or operating in Alaska. At the tactical-level, the 3 ASOS/WE is collocated with the 1-25 SCBT at Fort Wainwright, AK. They provide weather support for both tactical and garrison operations, observe the atmosphere and evaluate and tailor forecast products to produce Mission Execution Forecasts and staff briefings. 3 ASOS/WE also supports 1-25 SCBT tactical unmanned aerial vehicle (T-UAV) opera-tions. The Alaska Army National Guard operates the Fort Richardson Army Airfield.

Army National Guard (ARNG) Artillery

In the ARNG Modular Force, there is one 6-solder team per Fires Battalion in the Brigade Combat Team (BCT), providing 34 teams with six soldiers each, for 204 soldiers. In the Fires BDE there are 3 MET teams required per BDE providing 21 teams with 6 soldiers each, for a total of 126 soldiers; how-ever, all Fires BDE TABs are authorized only one MET team for a total of 48 soldiers. The ARNG is au-thorized 252 soldiers in the Artillery Meteorological Teams.

The ARTY MET sections provide upper air observations at least 39 training days each year sup-porting artillery live fire during Annual Training and monthly Inactive Duty Training. The ARTY MET sec-tions support an average of 20 live fire training days and annually expend in excess of 100 balloons per section. The ARNG's ARTY MET Teams use the Meteorological Measuring Set (MMS), AN/TMQ-41A.

<u>Army Corps of Engineers</u>

In its civil operational activities, the Corps of Engineers (COE) uses a network of about 10,850 land-based gages. 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 COE funds or partially funds 58 percent (6350) of all the gages it uses. Meteorological gages commonly measure pre-cipitation and temperature as a minimum. Most sites also measure hydrological data. All data are 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 pre-cipitation information from 877 of meteorological sites. Similarly, COE transfers funds to the U.S. Geo-logical Survey to maintain precipitation data collection from about 2400 sites, while the COE maintains the rest. Seventy-five percent of all COE sites provide real-time data via satellite, microwaves, meter-bursts, landlines, or radio. Data from COE gaging sites are available to other federal, state and local agencies. All COE data are made available to the National Weather Service. Most of the data are also used by other agencies.

<u>United States Army Space and Missile Defense Command (USASMDC)</u>

The High Energy Laser Systems Test Facility (HELSTF), an USASMDC directorate located on

White Sands Missile Range, is an Army element of the DOD Major Range and Test Facility Base with the mission of high-energy laser (HEL) test and evaluation for future Army and sister Service HEL weapons. In addition to HEL 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 HEL testing by providing measurements of atmospheric conditions that are extremely important to propagation of any HEL beam thru the atmosphere. Many unique meteorological instruments are maintained to sup-port this critical data collection for HEL testing. The HELSTF meteorological team also supports critical safety analysis of atmospheric dispersion for the very toxic laser fuels used.

U.S. Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC, which provides operational support for the Ronald Reagan Ballistic Missile Defense Test Site (RTS). The RTS meteorological services support contractor provides meteorological support for range activities including missile operations within the atoll, remote island missile launches including Wake Island, intra-atoll transportation (marine and aircraft), and emergency operations support.

A full suite of surface and upper air observing equipment is available for support of these operations. Three fixed upper air sounding systems (two utilizing GPS radiosondes) are located on Kwajalein and Roi-Namur. One portable GPS upper air system is available for deployment to remote locations providing upper air soundings. A dual-polarized -Doppler S-band weather radar provides weather surveillance from Kwajalein Island, and Doppler C-band weather radar is available for operations at Wake Island. Two POES satellite receivers (one mobile) both having McIDAS display and management systems, and one geostationary satellite receiver provide access to satellite imagery and data processing and analysis. An intra-atoll mesonet and lightning detection network round out the sensors available to RTS forecasters at Kwajalein. Lightning prediction and detection at Wake Island is supported by a thunderstorm sensor and field mill combination. In cooperation with NASA/GSFC, RTS weather continues to support global climate studies through the Tropical Rainfall Measurements Mission and the follow-on program of Global Precipitation Measurement and a smaller program of monitoring the solar-earth radiation flux for NOAA/ERL.

Figure 3-DOD-22. USASMDC is responsible for meteorological support to the Ronald Reagan Ballistic Missile Defense Test Site in the remote Kwajalein Atoll. (US Army Released)

## WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDT&E)

Under Army-AF agreement, the Army has responsibility for weather support for research, develop-ment, test, and evaluation (RDT&E) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The Corps of Engineers (COE), and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research re-lated to soldiers performance in the range of weather conditions expected to be encountered in all thea-ters of operations. The Army Test and Evaluation Command (ATEC) is responsible for operational mete-orological support to Army RDT&E.

<u>Army Corps of Engineers</u>

The Corps of Engineers (COE) is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The Topographic Engineering Center (TEC), and the Cold Regions Research and Engineering Laboratory

(CRREL) of COE's Engineer Research and Development Center (ERDC), develop Tactical Decision Aids (TDAs) to interpret the impact of weather on terrain to enhance Army operations. TDAs are transitioned to the Digital Topographic Support System (DTSS) and the Commercial Joint Mapping Tool Kit (CJMTK). Under its military mission, CRREL, Hanover, NH, provides support to Army weapon systems RDTE with all season solutions for mitigating adverse environmental effects on Army operations. CRREL conducts basic and applied research to investigate energy and mass transfer process at and near the terrain surface. Energy propagation and interaction across the electromagnetic, acoustic, and seismic spectral regions sees special emphasis, particularly with regard to dynamics in propagation caused by properties and processes of materials near the terres-trial surface. CRREL develops databases and models for predicting the state of the terrain including sur-face temperature, and tactical decision aids supporting mobility analysis and sensor performance. In part-nership with TEC, Alexandria, VA, these products transition to various research and engineering programs including advanced technology demonstrations and specific programs of record such as DTSS and CJMTK.

Army Materiel Command (AMC)

The Army Materiel Command (AMC) is responsible for the research, design, development, test, and evaluation of equipment to satisfy the Army's requirements for meteorological support. AMC provides climatological and meteorological support to RDTE projects involving electro-optical sensors, atmospheric and obscurant effects on systems and their performance. It is also responsible for determining weather impact critical threshold values and the environmental sensitivities of battlefield systems, including sol-diers. AMC has several Major Subordinate Commands (MSCs) and elements carrying out weather re-search and development responsibilities including the Research Development and Engineering Command (RDECOM), which has responsibility for the Army's Research Development and Engineering Centers (RDECs) and the Army Research Laboratory (ARL).

The Army Research Laboratory Battlefield Environment (BE) Division has a robust program in de-veloping very high spatial and time resolution characterizations of the lower atmosphere using both meas-urements and numerical models. This research is particularly focused on characterizing and predicting higher resolution effects caused by complex and urban terrain. The focus of RDT&E is in the near-surface boundary layer domain that is most critical to Army applications. RDT&E includes characterizing aerosols and CBRN contaminants in the atmosphere and on predicting more general impacts of weather on Army systems, sensors, personnel and operations. Research addresses how to assimilate battlefield meteoro-logical observations into diagnostic and prognostic numerical weather models and how to fuse forward area observations into these short term forecasts or 'nowcasts" to correct for actual local conditions and improve actionable weather information.

The Battlefield Environment Division of the ARL Computational and Information Sciences Directorate (CISD) has a long history in atmospheric science research and applications. The Division consists of three Branches located at Adelphi, Maryland and White Sands Missile Range, New Mexico. The three branches combine basic and applied research programs in the areas of: meteorological modeling and modeling applications at high space and time resolution and the effects of complex terrain; atmospheric sensing of aerosols and contaminants using laser scattering, spectral analysis, multi-wavelength imagers, and lidars; atmospheric and aerosol propagation including electromagnetic and acoustic signal and target effects modeling; meteorological measurements as part of the "develop-verify-improve-verify" modeling and measurement cycle; and advanced weather impact decision aids for Command and Control and for Intelligence, surveillance, reconnaissance and target acquisition. The Division also provides liaison per-sonnel between Army weather R&D and the coupled programs at the Air Force Weather Agency and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) IPO. These positions fo-cuses on coordinating technology transitioned from the BE Division into Army and Air Force fielded sys-tems.

The vision of the Battlefield Environment Division is to enhance Warfighter effectiveness through environmental knowledge and technology. The mission statement expands on this vision and is "to per-form research that solves complex Army-scale atmospheric problems and results in joint weather intelli-gence and Army-specific products for global Warfighter survivability, lethality, mobility, and situational awareness." The BE program addresses these Army needs for both current and future Army operations such as the Future Combat System (FCS), as well as providing answers in related areas such as home-land security and response to man-made and natural disasters.

BE Division and the Army Project Director- Integrated Meteorological System (PD-IMETS) office are partnering with Air Force Weather in new programs such as the development of a common Joint Envi-ronmental Toolkit (JET). The Army IMETS Battle Command (BC) 6.4 software and several Air Force weather system software baselines are to converge as a single weather forecasting software tool in the DCGS-A Weather Services. The Army will add command and control interfaces and weather effects tactical decision aid products such as the Tri-Service Weather Effects Decision Aid (TS-IWEDA). The com-bined JET-IMETS software will transition to the Distributed Common Ground Station-Army (DCGS-A) and Army software Block 2+ to enhance weather capabilities for net-centric Army support. POR IMETS/DCGS-A weather products can be accessed through a web-browser, client server applications, or overlaid on the user's Common Operational Picture (COP) through web services such as publish and subscribe (PASS). Current client applications will be web-enabled over time. IMETS/DCGS-A Weather Services technologies will continue to provide net-centric weather support to Army Battle Command and Future Combat Systems (FCS) as DCGS-A Weather Services.

The Atmospheric Modeling Applications Branch addresses the development of the next generation mission execution forecast model (very short term forecasts), web-enabled tactical decision aids, and avia-tion weather route planners for manned and unmanned systems applicable for DOD and DHS missions.

Meteorological forecast model applications are focused on the Weather Running Estimate-Nowcast (WRE-N) and Meso/micro-scale Numerical Weather Prediction development, improvements, and evaluation. The WRE-N is a combined analysis and "nowcast" model system that will provide the DCGS-A with a capability to satisfy the stated nowcasting requirement. The WRE-N system will produce locally-updated high resolution meteorological data in 3-hour forecast blocks, tailored for execution-level planning and decision making applications. As battlefield weather conditions change, the WRE-N will produce rapid and continuous "local corrections" to regional scale mission planning operational forecasts, retain consistency with theater-wide operational forecast guidance from Air Force and joint DOD weather cen-ters, and insure effective assimilation and fusion of local battlefield weather observations into each WRE-N modeling cycle. Such fine-scale battlefield weather modeling work leverages the ARL High Perform-ance Computing (HPC) capabilities to facilitate examination of the applicability of new atmospheric pre-diction models for Army scales, that is, at horizontal coverage of hundreds of kilometers and grid spacing of one kilometer or less, and test new boundary layer closures and data assimilation methodologies.

Warfighter Decision Aids developed in the branch utilize meteorological model gridded output to provide the commander a tactical advantage with validated and verified, web-enabled, tactical decision aids and associated databases that describe the impacts expected and the resulting performance degra-dation due to weather for both friendly and threat systems, allowing for analysis and adjustments in tactics and weapon system selection before enemy engagement. Decision aids play an important role in the mission planning process associated with both man in the loop and autonomous command and control systems.

Work to develop Unmanned System Applications has focused on the Aviation Weather Routing Tool (AWRT) as the primary end product. It addresses a major shortfall in providing accurate weather effects information to manned and unmanned aircraft mission commanders. The AWRT may be considered as a sophisticated tactical decision aid that will generate a highly-intuitive, 4-D graphical "fly through" dis-play of adverse weather effects on aircraft systems. Perhaps more significantly the AWRT will employ a computationally efficient automated search algorithm to identify optimum routes that minimize adverse weather effects along the flight path.

The BE Atmospheric Dynamics Branch addresses basic research, atmospheric measurements, numerical modeling and applications focused on the near-surface, high resolution dynamics of the boundary layer atmosphere that impact the Soldier and his systems. Projects and capabilities in the branch include:

Efficient and fast-running high resolution (sub 1 km) atmospheric models are developed that can provide a diagnostic 3D picture of wind fields in urban domains and over complex terrain. This capability provides a near real time update of average urban wind flow around buildings for their effects on CBRN, smoke screening, turbulence and wind effects on platforms and sensors.

Urban meteorology and boundary layer turbulence experiments are undertaken to highly instrument the flow around individual structures and to resolve the properties of atmospheric turbulence in the re-gimes between 3D isotropic turbulence and 2D surface layer turbulence for their effects on optical sys-tems and micro platforms. These data extend the basic research into atmospheric turbulence and support the verification and development of new wind models and optical propagation effects and simulation models.

Research is performed focused on poorly understood stable atmospheric boundary layer phenom-ena aimed at better characterizing intermittent nocturnal flow features and the capping of the boundary layer that can concentrate airborne hazards. Distinct layers in the urban domain include the Urban Mixed Layer (UML) well above the buildings, the Urban Surface Layer (USL) at the tops of the buildings, and the Urban Canopy Layer (UCL) representing the layer below the tops of the buildings and down to the street level. The features of these layers can be resolved remotely using instrumentation such as LIDAR's and radiometers.

Modeling applications for the effects of fine scale urban meteorology include development of a new urban smoke and dust transmission model for urban infantry war fighting simulations. The model uses the R&D performed for urban boundary layer dynamics with the transport, dispersion, and optical line of sight transmission to predict the effects on target acquisition and sensor performance in urban do-mains.

Bio-inspired environmental awareness for autonomous and semi-autonomous systems uses biomi-metic and biologically inspired approaches to sense and react to the microscale environment of platforms and sensors; and in particular to develop capabilities to automatically sense and avoid hazards to their operations, and to improve the reconnaissance, surveillance and search functions of small robotic devices.

The BE Atmospheric Sensing Branch currently has no personnel at WSMR. However, various branch personnel have participated in experiments and other work at WSMR over the past several years and have several proposals for work that would be done in part at WSMR locations. The Atmospheric Sensing Branch develops sensing technologies for scientific and operational sensing of the state of the atmosphere, acoustic propagation, and aerosols. Recent work has focused on the development of ultra-compact Doppler Lidar systems; experimental and theoretical developments to better understand acoustic propagation in urban environments; and aerosol measurement programs.

The Army Research Office, Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamical and physical 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 oc-casional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer over land, where the Army operates. Objectives of the research are to de-velop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding, modeling, and quantifying of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heteroge-neous terrain features on airflow, and the development of natural obscurations

Figure 3-DOD-23. The IMETS Vehicle Mounted Configuration. (US Army Released)

throughout the diurnal cy-cle. 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. Special funding areas 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 (DEPSCoR) 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. The primary research focus continues on the analysis and understanding of the stable boundary layer, which is augmented by external funding as a special program. Activities include transitioning coding for stable boundary layers, based on new theoretical developments to the WRF model library for use and test by AFWA and academic users.

Communications Electronics Command (CECOM), a major subordinate command of AMC, provides support to developing and fielding weather programs through the following organizations: Logistics Readiness Center (LRC), Research, Development and Engineering Center (RDEC), Software Engineering Center (SEC), and Safety office. The CECOM LRC is the level II manager of the Meteorological Measuring Set (MMS) program.

RDEC's Communications-Electronics Research Development Engineering Center (CERDEC), In-telligence and Information Warfare Directorate provides technical management and support to the Program Manager, Intelligence and Effects and Program Manager, Night Vision/Reconnais-sance, Surveillance, and Target Acquisition for the IMETS and the MMS-Profiler. A brief description of each of these programs shows CECOM's involvement.

Meteorological Measuring Set (MMS), 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 acquisi-tion users. The system is a non-developmental item (NDI). All active Army units and National Guard Bu-reau are equipped with the MMS.

The Meteorological Measuring Set-Profiler (MMS-P) AN/TMQ-52 and AN/TMQ-52A systems. The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. The Profiler design will support the new generation of artillery weapons. Profiler provides highly accurate MET data to adjust artillery fire and achieve first round hits and fires for effect. The system provides MET data on demand with data staleness of less than 30 minutes. The system will include frequent and update meteorological messages that enhances the meteorological validity over a larger battle space than the 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, radiosondes, and satellite-based sources, (such as boundary data from communications satellites and, in a future program block improvement, polar orbiting meteorological satellites) through onboard satellite receiving capability. The data affects the operation of the mesoscale meteorological model and for post-processing of the data in order to generate meteorological messages. 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. The Profiler Program successfully executed a development and testing program culminating in an Initial Operational Test and Evaluation (IOTE) 1Q FY05. Four System Design and Develop-ment (SDD) models have been converted to a Low Rate Production configuration with 13 additional LRIP system produced. Full Rate Production (FRP) was approved at a FRP Decision in FY05. Thirty Six full rate production systems have been programmed through FY09.

<u>Army Test and Evaluation Command (ATEC)</u>

The Developmental Test Command (DTC), a subordinate command of U.S. Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to Army research, development, test and evaluation (RDT&E). 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 RDT&E activities at eight Army installations. Because much of the operational meteorological support workforce at the Army ranges is or soon will be eligible to retire, the Program has implemented an intern program to recruit and train entry-level scientists to ensure continuity in specialized meteorological support services as senior employees retire.

The Army RDT&E Meteorology Program is continuing to collaborate with the National Center for Atmospheric Research (NCAR) on enhancements to the ATEC Four-Dimensional Weather (4DWX) System, which is the backbone of the meteorological support infrastructure at the Army test ranges. Major system components include 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. In FY07 the 4DWX program took delivery of a DOD high performance computer (HPC) which enables operational mesoscale ensemble forecasts to support major DTC test operations. System enhancements during FY08 include completion of an improved meteorological data archival/retrieval system with automated data quality control checks. During FY08, the 4DWX program also completed its transition from Mesoscale Model Version 5 (MM5) to the next-generation Weather Research and Forecast (WRF) model. The MM5 and WRF mesoscale models are used operationally in both predictive and ana-lytic modes to provide detailed information about the past, current, and future structure of the atmosphere over the Army's test ranges. For ensemble applications, both MM5 and WRF are used as members of the ensemble set, which typically uses 30 members with varying physics packages, boundary or initial conditions, and model type. System enhancements during FY09 will include improvements to the WRF model's capability for deterministic numerical weather prediction at the test ranges, assimilation of new types of data, development of a prototype next-generation data assimilation approach, and continued development of ensemble and probabilistic techniques. ATEC 4DWX modeling capabilities include MM5- or WRF-based real-time four-dimensional data assimilation (RT-FDDA) at seven Army test ranges and Global Meteorology on Demand (GMOD), a globally-relocatable mesoscale modeling system to support Army RDT&E (including DTC distributed and virtual testing) at locations other than the Army ranges. Output from the 4DWX mesoscale model 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 Division at Dugway Proving Ground's West Desert Test Center serves as the DTC Program Manager for Meteorological Support to Army RDT&E. Specialized services provided by the Division include: (1) technical assistance to the DTC operational meteorological teams/branches; (2) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; and (3) technical assistance to the DOD CB defense modeling com-munity in the development of new CB hazard assessment models. Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, and CB hazard assessment.

Army Medical Research and Materiel Command

The U.S. 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 is directed towards 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 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 dis-mounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days. USARIEM is working through an MOA with the Army Research Laboratory Battlefield Environment Division to implement thermal models on the Distributed Common Ground Systems – Army Weather Services.

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. 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.

# DEPARTMENT OF ENERGY
# OPERATIONAL AND RESEARCH WEATHER PROGRAMS

The overarching mission of the Department of Energy (DOE) is to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex. DOE's weather- and climate-related operational and research programs contribute in specific ways to this departmental mission.

## OVERVIEW OF DOE OPERATIONAL AND RESEARCH METEOROLOGICAL PROGRAMS

The need for site-specific meteorological services at DOE Federal facilities was first recognized in 1944, with the development, fabrication, and testing of atomic weapons and their accompanying national security and nuclear safety issues. In response to this need, DOE has established, operated, and maintained meteorological programs and undertaken various atmospheric research projects at many of its reservations and field offices.

Operational meteorological program requirements were subsequently augmented by the passage of the Clean Air Act and its amendments, reinforced by several DOE Orders that specify requirements for meteorological services to protect the environment. Consequently, a meteorological monitoring program has become an essential component of each DOE site. The acquisition of quality-assured meteorological data, provision of weather forecasting services, and development of site-specific climatology from these meteorological programs are important elements of the DOE Integrated Safety Management System (ISMS) because these elements contribute substantially to the implementation of site-wide personnel safety programs and support the following evaluations:

- Protection of facility workers and the public from severe weather (e.g., lightning, tornadoes, hurricanes), cold weather exposure, and heat stress, sufficient to meet Occupational Safety and Health Administration (OSHA) regulations
- Development of nuclear safety and chemical safety documentation (e.g., Safety Analysis Reports and Documented Safety Analyses)
- Establishment of diagnostic and prognostic consequence assessment elements of an emergency management response system to meet the requirements of DOE O 151.1C and the principles of DOE G 151.1-1
- Preparation of air, surface water, ground water, and waste management permits to support environmental protection and compliance activities that comply with U.S. Environmental Protection Agency regulations
- Preparation of impact analyses for construction, operation, deactivation, and decommissioning of projects and missions requiring National Environmental Protection Act determinations

The atmospheric sciences contribute to the successful implementation of many of DOE's mission elements. Meteorological data acquisition programs, analytical assessments requiring meteorological information, and weather forecasting operations are integral to meeting DOE goals. Understanding the nature of the atmospheric domain, with its various dynamic and chemical aspects of energy-related phenomena is vital to DOE goals for national energy security, scientific discovery and innovation, and environmental responsibility. For instance, an accidental release of a radioactive material, or a chemically or biologically toxic material, into the atmosphere can potentially have serious acute and chronic health effects, as well as long-term environmental consequences. Meteorological transport and diffusion processes play a key role in determining the fate of radioactive, chemical, or biological agents released into the atmosphere; including those resulting from malevolent acts. 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 local atmospheric processes necessary to establish real-time and projected atmospheric transport and diffusion conditions.

DOE administers operational meteorological activities through various offices, such as the Office of Health Safety and Security, the National Nuclear Security Administration (NNSA), and the Office of Envi-ronmental Management, that have missions linked to the atmospheric sciences. The Office of Science (SC) is responsible for managing DOE's climate change research programs. SC Climate Change Re-search is described in detail in the interagency report: Our Changing Planet, FY 2009. Activities at DOE sites include support to daily operations and national defense programs, all of which require fundamentally sound and well-managed meteorological monitoring programs.

## WEATHER SUPPORT TO DAILY OPERATIONS

Operational support programs include daily-customized weather forecasting services, support to national defense projects and homeland security, onsite meteorological monitoring programs, climatology services, occupational safety and health program support, and emergency preparedness and response program support. Each meteorological monitoring program is primarily directed toward the support of emergency preparedness and response programs and focused on protecting the environment and the safety and health of the onsite work force and the public.

Operational meteorological programs are conducted at Argonne National Laboratory, Brookhaven National Laboratory, Idaho National Laboratory (INL), Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Nevada Test Site (NTS), Oak Ridge Reservation (ORR), Pacific Northwest Na-tional Laboratory and Hanford Site, Pantex Plant, Sandia National Laboratory–Albuquerque, Savannah River Site (SRS)/Savannah River National Laboratory, and the Waste Isolation Pilot Plant. Some of these DOE sites maintain 24-hour weather watches for severe weather conditions that have the potential to im-pact site operations and construction projects, damage property, or threaten lives. For example, DOE-wide lightning safety initiatives, which are becoming integral elements of ISMS, are supported by DOE operational meteorological programs at such sites as NTS, Hanford, SRS, and INL. The Nevada Site Of-fice, which manages NTS, has developed a site order for implementation of lightning protection measures.

Several DOE field offices and their associated sites and facilities cover large areas, called reserva-tions (e.g., INL, ORR, NTS, Hanford, and SRS). In addition, several DOE sites are situated in areas of complex topography and heterogeneous surface characteristics (e.g., land-water interface, mountain-valley morphology) that influence local weather and airflow trajectories. The latter are important for their influ-ence on atmospheric transport and diffusion. For these reasons, and to ensure the protection of public health and safety and the environment, onsite meteorological monitoring programs are an essential part of DOE atmospheric science programs.

Some DOE weather monitoring 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 sparse to non-existent. Weather observations taken at a few DOE field sites are entered into the NWS database via the NWS meteorological data ingest and display system. Some DOE sites use NOAA's Advanced Weather Information Processing System, as well as vertical profilers and meteorological monitoring networks.

## METEOROLOGICAL RESEARCH ACTIVITIES

Currently, DOE does not support any weather-related meteorological research. As stated above, SC does support Climate Change Research as reported in Our Changing Planet, FY 2009.

## DOE METEOROLOGICAL COORDINATING COUNCIL (DMCC)

The DOE Meteorological Coordinating Council (DMCC) was formed in 1994 to coordinate meteorological activities among the field offices to enhance cost-effectiveness and productivity and to leverage synergistic opportunities. DOE has delegated the operation of its site/facility meteorological programs to DOC/NOAA and non-Federal for-profit M&O contractors. The DMCC membership is therefore composed of subject matter experts from within the DOE complex, representing the three components with operational responsibilities for these programs:

- Department of Commerce (DOC/NOAA) under an Interagency Agreement;
- Management & Operating (M&O) contractors
- Private contractors

The DMCC operates as a subcommittee of the DOE Emergency Management Issues Special Interest Group (EMI SIG) and has a web page that can be accessed directly or through the web page of the Subcommittee for Consequence Assessment and Protective Actions. DMCC also issues an annual report as part of its presentation to the EMI SIG Steering Committee.

A current DMCC project is to improve the provision of quality-assured meteorological information and execution of transport and diffusion models that meet software quality assurance requirements. Products of the DMCC include evaluations of meteorological requirements contained in DOE orders and guidance documents, site meteorological program peer reviews (i.e., meteorological program assist visits), and, as needed, customized technical assistance. The DMCC developed an Assist Visit Guide to enable DOE/NNSA sites to perform their own self-assessments.

# DEPARTMENT OF HOMELAND SECURITY WEATHER PROGRAMS

The Department of Homeland Security (DHS) has three primary missions: Prevent terrorist attacks within the United States, reduce America's vulnerability to terrorism, and minimize the damage from potential attacks and natural disasters. The department's first priority is to protect the nation against further terrorist attacks. Component agencies will analyze threats and intelligence, guard our borders and airports, protect our critical infrastructure, and coordinate the response of our nation for future emergencies. Besides providing a better-coordinated defense of the homeland, DHS is also dedicated to protecting the rights of American citizens and enhancing public services, such as natural disaster assistance and citizenship services, by dedicating offices to these important missions. DHS has five major divisions, called "Directorates": Border and Transportation Security (BTS); Emergency Preparedness and Response (EPR); Science and Technology (S&T); Information Analysis and Infrastructure Protection (IAIP); Management. Besides the five DHS directorates, several other critical agencies were folded into the new department or created when it was formed: Federal Emergency Management Agency, U.S. Coast Guard; U.S. Secret Service; Bureau of Citizenship and Immigration Services; Office of State and Local Government Coordination; Office of Private Sector Liaison; and the Office of Inspector General.

DHS has the primary responsibility for ensuring that emergency response professionals are prepared for any situation in the event of a terrorist attack, natural disaster, or other large-scale emergency. This entails providing a coordinated, comprehensive Federal response to any large-scale crisis and mounting a swift and effective recovery effort. DHS will also prioritize the important issue of citizen preparedness, and educating America's families on how best to prepare their homes for a disaster and tips for citizens on how to respond in a crisis will be given special attention at DHS.

## FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

FEMA's mission is to "reduce the loss of life and property and protect the Nation from all hazards, including natural disasters, acts of terrorism, and other man-made disasters, by leading and supporting the Nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation." In carrying out its role, FEMA works with the federal scientific community and agencies to ensure that appropriate risk information – for hazards, vulnerabilities and consequences -- is used to execute this mission. 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 that among many things develops hurricane evacuation studies including inundation maps based on surge model simulation results from the National Weather Service's National Hurricane Center. These studies are used by state and local hurricane emergency management planners and decision-makers to develop their hurricane evacuations plans.

FEMA's main interest with OFCM is identifying, developing and/or utilizing the most appropriate meteorological information to calibrate its preparedness, response and recovery activities to build and deploy emergency management capability, and to design and implement mitigation measures which reduce the consequences 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 Ac-quisition (WG/PSDA) and the WG/PSDA's efforts to develop a current National Plan for Post-Storm Data Acquisition to coordinate and support the collection of perishable data after major storms. These data have applications in post-disaster mitigation activities, the NFIP flood hazard analysis, the FEMA National Hurricane Program hurricane evacuation studies, and other FEMA risk analysis activities, such as the Multi-Hazard Loss Estimation Methodology (HAZUS). The National Hurricane Program division is the principal FEMA contact point for most meteorology-related matters while the Risk Analysis Division is the primary contact for flood risk analysis.

## UNITED STATES COAST GUARD (USCG)

Although no U.S. 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.

USCG conducts the International Ice Patrol (IIP) under the provisions of the International Convention for Safety of Life at Sea (SOLAS). The IIP 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 icebergs, and forwards 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 Ice Operations Division of the Marine Transportation Division at Coast Guard Headquarters. Field management of Coast Guard meteorological support services is accomplished at the Coast Guard Area and District levels.

# DEPARTMENT OF THE INTERIOR WEATHER PROGRAMS

The Department of the Interior (DOI), is the nation's principal conservation agency, charged with the mission "to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities." The following operational and research programs contribute to the Federal Meteorological Plan.

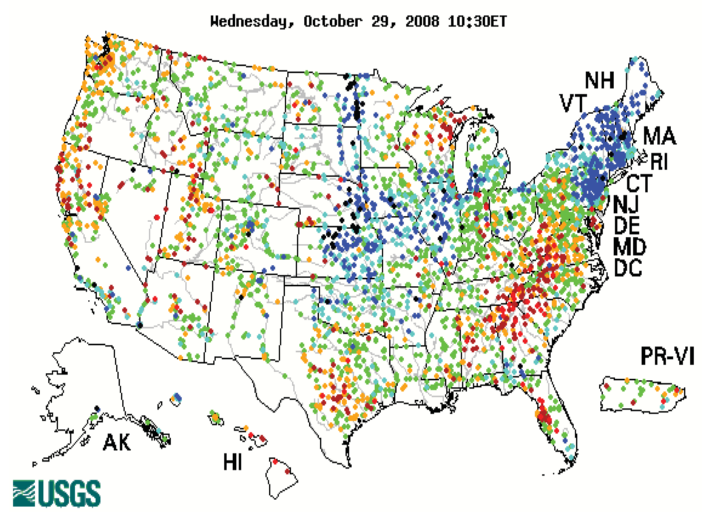
## UNITED STATES GEOLOGICAL SURVEY (USGS)

### WATER DATA

The USGS's Water Resources Discipline (WRD) collects streamflow, precipitation, water quality, ground-water level, and other water resources and climatological data as part of a national network and for a number of projects concerning rainfall-runoff, water quality and hydrologic processes. Currently, the USGS collects continuous hydrologic and meteorological data at about 8,900 surface water sites, 2,700 ground water level sites, and 1,600 water quality sites. Periodic records are collected at approximately 1,500 additional surface water sites, 20,200 ground water sites, and 10,300 water quality sites. Precipitation records are collected at about 800 sites.

Data collected at most continuous-record USGS sites are transmitted from remote Data Collection Platforms (DCPs) to Wallops Island, Virginia via a Geostationary Operational Environmental Satellite (GOES). From the Wallops Island facility, data are rebroadcast to a domestic communication satellite (DOMSAT). Data are received from the DOMSAT by local readout ground stations (LRGS) procured by USGS. The USGS currently operates 21 LRGS which provide near-real-time data to the USGS's computerized National Water Information System (NWIS). Near-real-time streamflow data and ancillary information are provided to National Weather Service River Forecast Centers for river forecast points (Figure 3-DOI-1). Additional historical and real-time water resources data are available from the USGS database at NWIS Web (http://waterdata.usgs.gov/nwis/).

The USGS also collects precipitation samples at a number of sites to determine the atmospheric contribution of chemical constituent loads to runoff, and for defining the effect of atmospheric deposition on water quality and the aquatic environment.




| Explanation - Percentile classes | | | | | | |
|---|---|---|---|---|---|---|
| Low | <10 Much below normal | 10-24 Below normal | 25-75 Normal | 76-90 Above normal | >90 Much above normal | High |

Figure 3-DOI-1. Sample USGS Water Watch map of real-time streamflow compared to historical streamflow for the day of the year. Source: USGS Website (http://water.usgs.gov/waterwatch)

### CLIMATOLOGICAL RESEARCH

USGS carries out research in climate change, regional hydrology, the carbon cycle, coastal erosion, and glaciology. The Water, Energy, and Biogeochemical Budgets (WEBB) program is studying processes controlling water, energy, and biogeochemical fluxes at five small research watersheds in the United States. This program includes research on the effects of atmospheric and climatic variables on watershed processes. There are also a number of ongoing studies to characterize trends in hydrologic data and to relate these trends to climatic variables. Researchers are also using global and regional climate models to enhance understanding of the potential effects of climate change and climate variability on U.S. land and water resources.

As part of its glaciology program, the USGS maintains an observation program on three benchmark glaciers representative of different climatic zones of the western United States, one in Washington, one on the south coast of Alaska and one in the interior of Alaska. At each glacier, the program measures the winter snow accumulation, summer snow and ice ablation, air temperature, and runoff in the glacier basin. Beginning in 1959, this is the longest such record in North America. Analysis of this 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 atmospheric conditions in the northeast Pacific Ocean, including El Niño - La Niña events and the Pacific Decadal Oscillation.

To augment its glacier monitoring efforts, the USGS is using National Systems data to measure fluctuations of glaciers in Alaska, Washington, and Montana. Mountain glaciers are ideal subjects for these systems because they are remote, have an appropriate space scale, and require infrequent but repetitive observations. The observations have established a baseline of regional glacial conditions. The resulting and on-going archive of observations is being used to determine recent trends in glacier size and terminus location. In addition, techniques have been developed to generate derived products that provide critical glacial parameters, including DEMs, equilibrium line altitudes, and ablation rates. These products are being incorporated into a glacial runoff model of the South Cascade Glacier, Washington, where they are proving to be a valuable source of otherwise unavailable data.

## SNOW AND ICE STUDIES

USGS scientists are cooperating with scientists at the University of Washington, Seattle, to improve hydrologic runoff modeling of the snow pack in the Pacific Northwest through the application of data assimilation techniques. The assimilation uses passive microwave observations from the Advanced Microwave Scanning Radiometer, AMSR-E, and numerical integration of Maxwell's equations constrained by a snow pack model to determine the distribution of snow water equivalent across select drainage basins. Then the UW Variable Infiltration Capacity (VIC) model calculates the subsequent runoff, which is compared to USGS discharge measurements. If the calculated runoff is not within a specified amount of the measured runoff, the assimilation technique adjusts the snowpack characteristics and another iteration is carried out.

USGS, in cooperation with BLM, is using a variety of remote sensing data to monitor the rapid wastage of the piedmont lobe of Bering Glacier, Alaska. Landsat, Radarsat, ICESat, and Ikonos observations show that Bering Glacier is retreating rapidly and thinning in an accelerating retreat from an advanced position that resulted from a major glacial surge in 1993-95. The satellite data and ground-based observations have been combined to determine the surface flow velocities and calving rates of the glacier, and to monitor the expansion of Vitus Lake and Berg Lake, two large lakes whose boundaries include the glacier terminus. The rapid change in glaciation is having a large impact on nearby terrestrial and aquatic ecosystems.

## GEOMAGNETIC DATA

The Geomagnetism Program (http://geomag.usgs.gov) of the USGS Central Region Geohazards Team provides real-time, ground-based measurements of the Earth's magnetic field, which are an important contribution to the diagnosis of conditions in the near-Earth space environment of the sun, the solar wind, the magnetosphere, the ionosphere, and the thermosphere. During geomagnetic storms, brought about by the complex interaction of the Earth's magnetic field with that of the Sun's, both high- and low-frequency radio communications can be difficult or impossible, global positioning systems (GPS) can be degraded, satellite electronics can be damaged, satellite drag can be increased, and astronauts and high-altitude pilots can be subjected to enhanced levels of radiation.

Ground-based geomagnetic observatory data are complementary to those collected by space-based satellites; indeed, most of the hazardous effects on technological systems brought about by magnetic storms occur at or near the Earth's surface. Therefore, the Geomagnetism Group monitors the surficial magnetic field by operating 14 magnetic observatories in the United States and its Territories. The data from these observatories, plus 15 foreign observatories, are transmitted to the Group's headquarters in Golden, Colorado, where they are processed and analyzed. Data are then transmitted to the Space Environment Center (SEC) of the National Oceanic and Atmospheric Administration (NOAA) and to the U.S. Air Force's (USAF) Weather Agency at Offutt Air Force Base, Nebraska.

USGS observatories are operated in cooperation with Intermagnet (www.intermagnet.org), an international consortium overseeing the operation of nearly 100 geomagnetic observatories distributed around the globe. The USGS Geomagnetism Program is also an integral part of the National Space Weather Program.

VOLCANOLOGY AND VOLCANIC ASH PLUMES

Through its Volcanic Hazards Program, the USGS is responsible for monitoring volcanoes in the United States and issuing eruption forecasts and notifications. The USGS participates in the Working Group for Volcanic Ash (WG/VA) of the OFCM. This working group has prepared a National Volcanic Ash Operating Plan for Aviation. The purpose of the plan is to provide operational guidance by documenting the required procedures and information products of the government agencies responsible for ensuring safety of flight operations when volcanic ash has been erupted into the atmosphere. The agencies involved are the USGS, Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), and the U.S. Air Force.

The OFCM helps to administer funding from the FAA to the USGS to improve aviation safety through expanded volcano monitoring in Alaska where many historically active volcanoes underlie the heavily traveled air routes of the North Pacific region. Over the past decade with FAA support, the USGS's Alaska Volcano Observatory (AVO) has installed seismic networks at approximately two dozen volcanoes in the Aleutian Islands, bringing to 31 the number of Alaska's volcanoes under continuous real-time geophysical surveillance. Data and information from the AVO monitoring activities are integrated directly into the regional operational activities of the FAA, DOD, and NOAA/NWS to provide warnings for pilots and aircraft operators in the Alaskan region.

The United States. has experienced significant levels of volcanic activity recently. Augustine Volcano, located near Anchorage, Alaska, erupted from January to April 2006, finally settling back into quiescence that summer. AVO mounted a 24/7 monitoring response to characterize ash-cloud hazards to aviation and worked closely with the National Weather Service to provide ash-fall information to the public. AVO also has continued to closely monitor Cleveland volcano in Alaska, which has been erupting intermittently since 2001. Mount St. Helens, Washington, reawakened in September 2004 from 18 years of quiescence. The eruption has largely consisted of the extrusion of lava with activity confined to the summit area. However, occasional explosions have erupted ash to heights as great as 30,000 feet above sea level. USGS, NWS, and FAA have worked together to develop procedures and protocols to handle an erupting volcano situated between two major metropolitan centers.

Recognizing that many potentially dangerous U.S. volcanoes have inadequate or no ground-based monitoring, the USGS recently evaluated U.S. volcano-monitoring capabilities and published "An Assessment of Volcanic Threat and Monitoring Capabilities in the United States: Framework for a National Volcano Early Warning System (NVEWS)" (online at http://pubs.usgs.gov/of/2005/1164/). Results of the NVEWS volcanic threat and monitoring assessment are being used to guide long-term improvements to the national volcano-monitoring infrastructure operated by the USGS and affiliated groups. The most threatening volcanoes, those near communities and transportation infrastructure (ground and air) and with a history of frequent and violent eruptions, need to be well monitored in real time with an extensive suite of instrument types to detect the earliest symptoms of unrest and to reliably forecast behavior of the volcano. Waiting until unrest escalates to augment monitoring capabilities at these high-threat volcanoes puts people (including scientists in the field) and property at undue risk. Remote, isolated, or less frequently erupting volcanoes that nevertheless can pose hazards to airtraffic corridors require sufficient monitoring capability with ground-based instruments to detect and track unrest in real-time so that other agencies responsible for enroute flight safety can be kept apprised of the potential for explosive, ash-cloud-forming eruptions.

The Volcano Hazards Program has posted pages on its website devoted to practical guidance for dealing with ash hazards to transportation, communications, agriculture, water supplies, etc. See http://volcanoes.usgs.gov/ash.

## BUREAU OF LAND MANAGEMENT (BLM)

The BLM is one of five Federal Land Management agencies which have centralized Wildland fire weather operations at the National Interagency Fire Center (NIFC), in Boise, Idaho. The 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. Many of the capabilities that were centrally located in the old IAMS have been moved to other web sites.

### FIRE WEATHER WEBSITES

The principal Wildland Fire Management Information System (WFMIS) inputs remain the same with Remote Automatic Weather Station (RAWS) and National Lightning Detection Network (NLDN) informa-tion. BLM's new server system is called the BLM Wildland Fire Management Information Site (www.nifc.blm.gov). Additional fire management information is summarized and made available at the Desert Research Institute (wrcc.dri.edu and cefa.dri.edu) and the U.S. Forest Service Wildland Fire Assessment System (http://www.wfas.net/). Additionally, the BLM has utilized the Desert Research Institute's capabilities to respond quickly for website support.

### AUTOMATED WEATHER STATIONS

The BLM's RAWS Program primarily collects meteorological data for fire weather forecasting. However, use of BLM's RAWS data set by other non-fire users has generated sufficient funding to permit year-round operation of the entire network. The BLM's Resource Management and Oregon O&C (West-Side) also operate RAWS networks which are much smaller and have specific program requirements that differ from fire management.

### LIGHTNING DETECTION

In 1997, the BLM began contracting with a private vendor via the National Weather Service for lightning location data. Data are received at the NIFC in Boise, Idaho, and placed on the BLM WFMIS for qualified user access. Current plans are to continue the operation of the Alaska Automatic Lightning Detection System as an independent government-owned and operated system.

### FIRE WEATHER SUPPORT

The BLM's Remote Sensing / Fire Weather Support Unit (RSFWSU) at NIFC provides the full range of program management, equipment dispatch, field and depot maintenance, support and data services for the BLM and numerous other government agencies. This interagency-staffed and funded facility performs work under long term agreements with those agencies within the government having similar equipment and requirements.

### CLIMATE MONITORING

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 11 western states and Alaska. The operation of these sites ranges from seasonal to annual, taking 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.

### PORTABLE WEATHER STATIONS

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 a fire line and can be rapidly relocated to points desired by Fire Behavior Analysts 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. Fire managers have also increased the use of FRWS to monitor intentionally-initiated prescribed burns.

Currently, 42 FRWS systems are cached at NIFC. FRWS collect, store, and forward data by interrogated voice radio with new data available every fifteen minutes. Satellite data can be retrieved from multiple websites, and hourly satellite data is available to Fire Weather Forecasting Staff for spot forecasts and fire support from all central locations (Geographic Area Coordination Centers, NIFC, etc.). Using the personnel and resources available at the RSFWSU, the BLM offers a rapid meteorological support capability that is unique across the federal government.

## BUREAU OF INDIAN AFFAIRS (BIA)

The Bureau of Indian Affairs collects atmospheric data to evaluate potentially irrigable Indian Trust lands in the Southwest. The Bureau also collects and shares fire weather data with other Federal agencies while participating in fire management activities for local and interagency use. Currently, BIA operates 69 fire weather RAWS stations (permanent), 5 “manual” weather stations, 13 portable RAWS stations used for Prescribed Fire, and 10 RAWS deployed on emergency stabilization projects.

## MINERALS MANAGEMENT SERVICE (MMS)

The Minerals Management Service (MMS) gathers offshore meteorological data for use in the management of offshore oil and gas resources and sources of alternative energy. The data are used in air quality and oil-spill modeling, model development, and other research projects.

MMS operates a radar wind profiler (RWP) at the Louisiana Universities Marine Consortium (LUMCON) facility in Cocodrie, Louisiana. Data collected at this site may be accessed at http://weather.lumcon.edu/weatherdata/doppler. The data will be applied to regional models for evaluating impacts from emission sources on ozone, fine particulate matter, and regional haze. The Service, in a cooperative agreement with The University of Houston (UH), operates an RWP at the UH Coastal Research Center (UHCRC) near Galveston, TX. The profiler will collect data for three years through FY 09.

The MMS has completed a meteorological and air quality modeling analysis in and around the Breton National Wilderness Area (NWA), which is a PSD Class I area located off southeastern Louisiana. MMS is currently sponsoring the operation of a visibility monitoring station near the Breton NWA IMPROVE site. The objective is to study the relationships between visibility, haze, ozone, PM2.5, dew point depression, and mixing height and to determine the source region(s) for haze, haze precursors, resulting is low visibility conditions near the Breton Island NWA. The study will utilize two additional visibility monitors operated by the Coastal Marine Institute (CMI) at Louisiana State University (LSU). Satellite data will be collected to measure optical depth and to determine source regions of atmospheric pollutants.

Other ongoing studies in the Gulf of Mexico include (1) an effort to evaluate the effects of ozone deposition/chemical mechanism enhancements on air quality model performance over the coastal marine environment and (2) a study to evaluate of the effects of satellite data assimilation on meteorological/air quality model performance. Copies of all final reports in past meteorological and air quality studies in the Gulf of Mexico may be found at http://www.gomr.mms.gov/homepg/regulate/environ/techsumm/rec_pubs.html.

A meteorological data collection effort was conducted by MMS along the Beaufort Sea shoreline in Alaska; five meteorological stations collected data starting in 2001. Four of these stations operated in FY 08 through an interagency cooperative program. The Service is analyzing the data gathered by these stations and will develop a mesoscale meteorological model for predicting ocean and ice circulation.

Another ongoing study in Alaska is an effort to develop an atmospheric modeling capability for the Cook Inlet/Shelikof region suitable for nowcast/forecast and research purposes. Among the objectives of this project is to develop an understanding of the mechanisms which drive low-level wind jets in the region, describe the vertical and thermal struc-

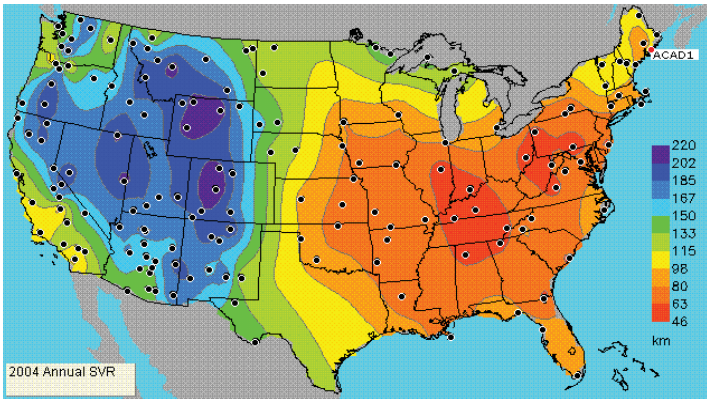



Figure 3-DOI-2. Annual average standard visual range (SVR), in kilometers, calculated from IMPROVE particle concentrations and locations of most of the IMPROVE and IMPROVE protocol sites. (http://vista.cira.colostate.edu/views/Web/AnnualSummary/ContourMaps.aspx)

ture of wind jets, and study the cloud fields and precipitation associated with high wind events in the region. For more information on the MMS Alaska Region Studies Program see http://www.mms.gov/alaska/ess/index.htm.

## NATIONAL PARK SERVICE (NPS) AND FISH AND WILDLIFE SERVICE (FWS)

The National Park Service monitors air quality and visibility in a number of national parks and monuments. Gaseous pollutant data are collected on continuous and integrated (24-hour to weekly) 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 every third day. Atmospheric light extinction is measured continuously and relayed to a central location for analyses.

### MODELING

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.

### JOINT MONITORING AND RESEARCH

The Fish and Wildlife Service Air Quality Branch and the NPS Air Resources Division operate under an interagency agreement and are located 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.

The NPS oversees the operation of the Interagency Monitoring of Protected Visual Environments (IMPROVE) network and the IMPROVE Protocol network in cooperation with the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Forest Service (USFS), the FWS, the BLM, and various State organizations. Currently, the network has about 170 sites, mostly funded by the EPA in support of their regional haze regulations and through other cooperators. The enhanced network allows a better characterization of visibility and fine particle concentrations throughout rural and remote areas of the country (Figure 3-DOI-2).

## 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 is the Watershed and River System Management Program (WaRSMP), which is being developed in partnership with the USGS. Information on WaRSMP is at http://www.usbr.gov/pmts/rivers/ .

Other key players in this effort include TVA, the Corps of Engineers, NOAA, NASA, NRCS, the University of Colorado and Colorado State University. This program provides a data-centered framework for science-based water resources decisio making. Major components are:

- Hydrologic Database (HDB),
- Modular Modeling System (MMS),
- RiverWare river system modeling framework,
- Stochastic Analysis, Modeling and Simulation (SAMS) system,
- Agricultural WAter Resources Decision Support (AWARDS) and

- Evapotranspiration Toolbox (ET Toolbox) system.

## HYDROLOGIC MODELING

The SAMS hydrologic modeling system 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 "Colorado River Interim Surplus Criteria: Final Environmental Impact Statement". Current Reclamation projects under WaRSMP include:

- Planning and developing HDB, MMS and RiverWare systems for the Gunnison, San Juan, Rio Grande, Yakima, and Truckee river systems;
- Development of expanded capabilities to allow HDB to function as the Database of Record which will document management decisions and the data used to make them for Reclamation's Upper and Lower Colorado regions as well as other participating offices.
- SAMS integration and testing for the lower Colorado and Truckee River Basins;
- 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-hour 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.
- Integration and testing of emerging Land Surface Modeling Products from NASA's Global Land Data Assimilation Systems for snow mapping, surface energy and water budgets and ET analysis and prediction for water operations management.
- Testing and development of weather and climate products from the Global Energy and Water Cycle Experiment (GEWEX) for water supply and demand forecasting.

## INSTRUMENTATION AND DATA ACQUISITION

NEXRAD estimates of precipitation are used for water supply and water delivery decision-making. Water managers can view the distribution of precipitation over watersheds that supply water to storage facilities, and examine the detailed spatial distributions of precipitation over the irrigated areas along with estimates of soil moisture, and evapotranspiration from crops and riparian vegetation.

The Watershed and River Systems Management Program focuses on integrating multi-disciplinary science into decision support systems that enable water managers to make the best deliveries of water to stakeholders.

Currently, Reclamation's HYDROMET system collects data from approximately 400 hydrometeorological data collection platforms (DCPs) which transmit data in real-time through GOES to Reclamation'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 BLM, Federal and state offices. Reclamation's primary real-time hydrometeorological information from the NWS, USGS, NASA, and other agencies is displayed on the AWARDS / NEXRAD / ET Toolbox web site: http://www.usbr.gov/pmts/rivers/awards/index.html

Water supply information from cumulative precipitation estimates from radar is also provided in areas where snowfall is an important source of water. Links directly to USDA Natural Resources Conservation Service and NOAA/National Centers for Environmental Prediction analysis and forecasting web sites are provided to further document the latest information.

## TECHNICAL INFORMATION

The National Xeriscape Demonstration Program (NXDP) was initiated by Reclamation to estimate the benefits of water conserving landscaping. In partnerships with States, field demonstration projects were conducted in Fargo ND, Austin TX, the Colorado Front Range, Phoenix AZ, and southern Nevada. Water savings ranged from 18 to over 50 percent in the demonstration projects, strongly suggesting water planners should consider this water conservation alternative as a supply development option.

## SNOWPACK ASSESSMENT

Snowmelt represents about 80% of reservoir storage in Colorado and is largely responsible for spring flooding events in the state. Therefore it is highly desirable to know snowpack characteristics, such as its snow water equivalent (SWE), its spatial and elevation distribution, and its evolution with time during the water year. With support of the Colorado Water Conservation Board (CWCB), Reclamation has adapted the Snow Data Assimilation System (SNODAS) for enhanced snowpack assessment in the state of Colorado. The SNODAS was developed by the National Operational Hydrologic Remote Sensing Center (NOHRSC), a National Weather Service unit, and data are acquired through the National Snow and Ice Data Center.

SNODAS consists of a spatially distributed

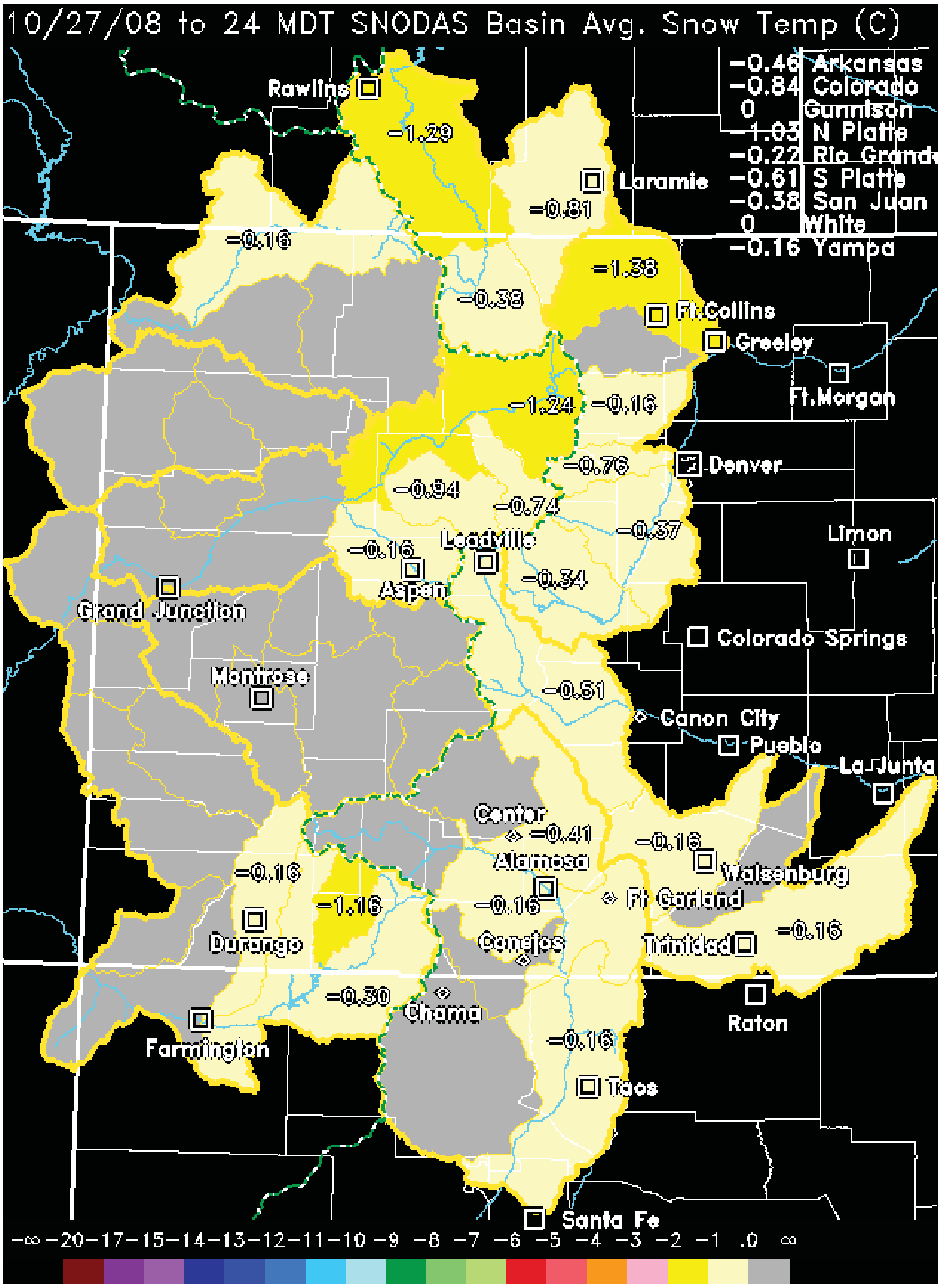



Figure 3-DOI-3. Snow Data Assimilation System (SNOWDAS) past 24 hour (28-29 Oct 08) Snowpack Temperature (C) in Colorado (http://www.usbr.gov/pmts/rivers/awards/Co/SNODAS/CoSnTavg.gif)

snow energy and mass balance model, coupled with an assimilation of all available SWE, snow depth, and snow cover data (from surface, aircraft, radar, satellite). Model outputs are at 1 km resolution and include SWE, snow depth, snowmelt, pack temperature, and sublimation. Comparison with data from Snow Telemetry (SNOTEL) sites and satellite imagery shows faithful representation of SWE and snow cover, respectively. Basin average SWE is substantially reduced over that of SNOTEL because the former is a basin-wide spatial average instead of an arithmetic average of a few high-elevation points. This difference is important hydrologically and holds the promise of coupling snowmelt with a hydrologic model to produce streamflow hydrographs. Such hydrographs would be extremely useful to the decision support systems of water management agencies such as the CWCB and Reclamation, with the ultimate aim of improved forecasting of water supplies and flooding. Colorado SNODAS products have been posted daily at http://www.usbr.gov/pmts/rivers/awards/SNODAS/index.html since October 2003. Future work will consist of verification of SNODAS outputs, improvement of precipitation inputs, and coupling to a hydrologic model.

# 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 (FCCC). In addition, over the past few years the DOS has played a central and active role in the development and implementation of a number of international science and technology initiatives including the Group on Earth Observations, the Carbon Sequestration Leadership Forum, the International Partnership for the Hydrogen Economy, the Methane-to-Markets Partnership, and Generation IV (a U.S.-led program working on new fission reactor designs that will be safer, more economical and secure).

Stratospheric ozone depletion has been recognized as a critical health and environmental problem for more than two decades. 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 this middle of this century. To date, these treaties have been signed and ratified by more than 193 countries, including the United States. These countries represent 99 percent of the world's production of ozone depleting substances. The State Department makes annual contributions to the Vienna Convention's efforts on scientific monitoring of the ozone layer.

The IPCC, which was established 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 scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. In doing so, the Panel draws on the expertise of thousands of scientists and technical experts. The IPCC is currently organized into three working groups, which examine (1) the state of the science, (2) impacts and adaptation, and (3) mitigation. In addition to preparing assessment reports, the IPCC also contributes to international negotiations through preparation and review of special reports and development of methodologies requested by the UNFCCC.

The UNFCCC was negotiated beginning in February 1991 and the Convention was open for signature in Rio de Janeiro at the Earth Summit in June 1992. As of May 2004, it had been ratified by 189 countries, including the U.S.. The ultimate objective of the Framework Convention is to stabilize greenhouse gas emissions at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system. It states that such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

In December 2007 at the Conference of the Parties (COP) to the UNFCCC, the United States agreed to the Bali Action Plan which was the start of a two year negotiation toward a new long term climate arrangement for the post 2012 era. As an adjunct to the UN process, the United States and sixteen other major economies responsible for roughly 80% of the world's economic activity and 80% of the world's greenhouse gas emissions founded the "Major Economies Process on Energy Security and Climate Change" (MEM). They have met in Washington, Honolulu, Paris, Seoul, and Lake Toyado, Japan, with more meetings planned for 2009 before the Copenhagen COP in December of that year.

Another multilateral effort is the Asia-Pacific

Partnership on Clean Development and Climate (APP). The seven countries that make up the Partnership – Australia, Canada, China, India, Republic of Korea, Japan, and the United States – are focused on clean development projects in partner countries. To date over 115 projects have been endorsed by the APP since January 2006. The US APP Program office in DOS has funded roughly $13 million worth of clean development projects in India and China to date.

In the context of meteorological and climate monitoring, as well as mitigating greenhouse gases and related impacts, DOS together with strong participation from USDA, DOE and other US government (USG) agencies, organized the Washington International Renewable Energy Conference (WIREC) in March, 2008. As the third international ministerial-level event on renewable energy, the conference drew over 3000 participants, with an additional 6000 attending the trade show and related events. Notably, the Ministerial Meeting at WIREC brought together 103 ministers representing energy, economic and scientific sectors of governments. In response to the call issued by the conference organizers, participants submitted over 140 pledge commitments related to implementation of renewable energy on behalf of organizations ranging from governments to civil society to the private sector. USG contributions include a total of 31 pledges made by 14 agencies, including DOS commitments anchored in the Asia-Pacific Partnership initiative.

Together these initiatives help our global capability to understand and address issues associated with climate change in a manner that supports broader sustainable development goals. In addition to its primary role in the fora listed above, DOS is active in several relevant interagency processes, including the Committee on Environment and Natural Resources (CENR) of the National Science and Technology Council, the Climate Change Science Program (CCSP) and its Interagency Working Group on Climate Change Science and Technology (IWGCCST). The CENR was established in 1993 to coordinate scientific domestic programs. CCSP was created in 2001 to “integrate federal research on global change and climate change” across thirteen federal agencies and is the umbrella to IWGCCST which was founded in 2002 and is a sub-Cabinet level group that reviews all programs that contribute to climate change science and technology.

In addition to the above, DOS responsibilities include, but are not limited to, international aspects of food policy, disaster warnings and assistance, WMO and UNEP activities, and international meteorological programs.

# 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 require the incorporation and use of timely weather and road condition information. The Federal Railroad Administration 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 rail operations and railroad employees. The Federal Transit Administration's 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.

## FEDERAL AVIATION ADMINISTRATION

### THE NATIONAL AIRSPACE SYSTEM (NAS) OF THE FUTURE

To address the growing demands on the NAS for the future, the 108th Congress and the Bush Administration promulgated and signed into law VISION 100 Century of Aviation Reauthorization Act (P.L. 108-176). The Vision 100 Act calls for an integrated, multi-agency plan to transform the nation's air transportation system to meet the needs of the year 2025, while providing substantial near-term benefits. The resulting Next Generation Air Transportation System (NextGen) Initiative will address critical safety and economic needs in civil aviation while fully integrating national defense and homeland security improvements into the future NAS.

Along with the private sector and academic community, the FAA, National Aeronautics and Space administration (NASA), and the Departments of Commerce, Defense, Homeland Security, and Transportation are working together with the Office of Science and Technology Policy to design and build NextGen. To coordinate this work, VISION 100 created the Joint Planning and Development Office (JPDO), which reports to the Senior Vice President for NextGen and Operations Planning within FAA's Air Traffic Organization (ATO).

Overseeing the work of the JPDO at the interagency level is a Senior Policy Committee that is chaired by the Secretary of Transportation and includes senior representatives from the participating departments and agencies, plus the Director of the Office of Science and Technology Policy. Among its key responsibilities, the Senior Policy Committee provides policy guidance and review; makes legislative recommendations; and identifies and aligns resources that will be necessary to develop and implement the Integrated National Plan.

Two principal FAA entities that report to the Senior Vice President for NextGen and Operations Planning are focused upon implementation of NextGen, especially in the near and medium term. They are the NextGen Integration and Implementation Office and the Aviation Weather Office. The role of the NextGen Integration and Implementation Office is to ensure that the plans for the several NextGen strategic thrusts, called solution sets, are coordinated and integrated for efficient near- and medium-term implementation across the FAA. One of the solution sets, called Reduce Weather Impact (RWI), is a portfolio of enhanced weather capabilities to support NextGen. A component of this solution set is NextGen Network Enabled Weather, a focused effort to enable and enhance weather data collection and dissemination by all NextGen users.

The role of the Aviation Weather Office is to plan and implement the RWI portfolio. In collaboration with stakeholders across FAA organizations and

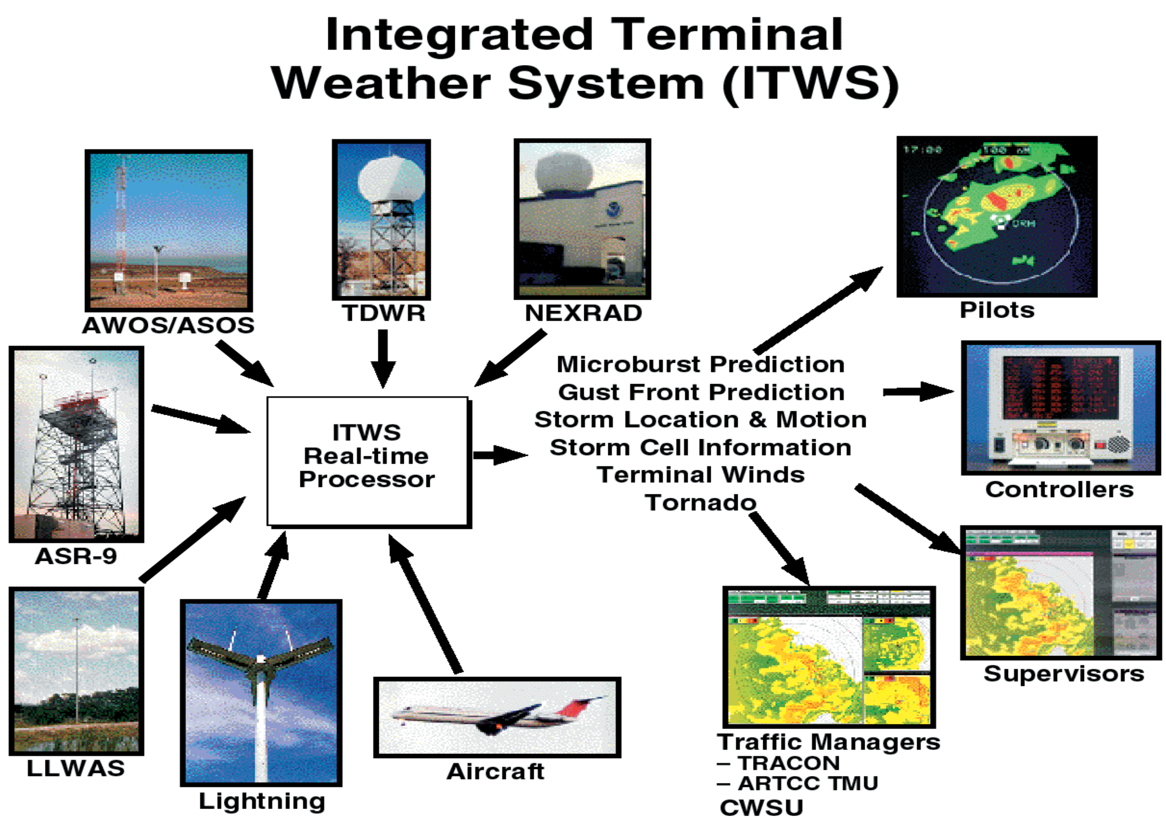



Figure 3-DOT-1. The ITWS integrates data from FAA and NWS sensors and systems to provide a suite of weather informational products.

the JPDO, the Aviation Weather Office establishes aviation weather requirements on behalf of all NAS users. It plans and executes the RWI solution set in conjunction with the NextGen Integration and Implementation Office.

The FAA RWI portfolio provides the solutions necessary to achieve NextGen requirements. The RWI solutions will provide ready access to accurate weather information by all air traffic managers, airline operations centers, and flight deck operational decision-makers. It will improve the comprehensiveness and accuracy of weather observations and forecasts and support the integration of weather information into decision support tools for those decision-makers. A key component of RWI is the development and implementation of an authoritative source for four-dimensional weather data (4D Weather Data Cube). The 4D Weather Data Cube will provide a comprehensive database of quality-assured observed and forecasted weather information.

The FAA NextGen Network Enabled Weather (NNEW) program establishes the information management capabilities necessary to quickly collect and disseminate needed weather data to NAS users. NNEW will be a net-centric distribution system for the 4-D Weather Data cube, which will provide uniform access to common weather parameters.

AVIATION WEATHER ACQUISITION AND SERVICES

One of the primary functions of the FAA ATO organization is the development and management of requirements for the FAA Capital Investment Plan. The ATO Operations Planning Service component manages the NAS Requirements Development program to align requirements, priorities, programs, and resources and to develop metrics to understand the impacts of weather on the NAS. The program develops strategic plans and defines weather requirements, policy, and standards.

Recent weather projects have focused on weather detection and display systems for pilots and air traffic controllers to ensure that aircraft avoid hazardous weather. The following paragraphs describe many of those projects.

The Integrated Terminal Weather System (ITWS) integrates 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 uses 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 param-

Figure 3-DOT-2. Corridor Integrated Weather System (CIWS) Display

eters such as convection, visibility, icing, wind shear, and down-bursts. ITWS has been installed at 26 locations, completing ITWS segment 1 (Figure 3-DOT-1). The current long range program has been limited to 22 ITWS operational and 4 support locations, which will cover about 35 high-activity airports that are supported by terminal doppler weather radars.

The Corridor Integrated Weather System (CIWS) will support advanced weather product generation to help reduce convective and other weather delays (Figure 3-DOT-2). The CIWS is expected to integrate information from the WSR88D and ASR-9 radars and from other observing sensors nationwide to produce weather information products focused on current conditions affecting terminal departure, en route, and arrival traffic. It will provide automated forecasts, using high-resolution graphics, of convective and winter weather, as well as echo tops in the 0-2 hour timeframe. CIWS will provide accurate, automated, and timely weather information to the traffic managers, area supervisors, and meteorologists in 8 Air Route Traffic Control Centers, 6 Terminal Radar Approach Control Facilities, and the Air Traffic Control System Command Center, as well as to airline operations center personnel. The CIWS demonstration system is undergoing a re-engineering effort to increase performance and maintainability, after which the transition to operational deployment is planned for the William J. Hughes Technical Center, for baselining into the NAS.

The Terminal Doppler Weather Radar (TDWR) program consisted of the development, 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 airports with high operations and frequent weather impacts. In addition, TDWR has the capability to identify areas of precipitation and the locations of thunderstorms (Figure 3-DOT-3). The FAA has 45 operational and 2 support TDWR systems. A service life extension program is underway to maintain and improve TDWR system capability.

Microbursts are weather phenomena that consist of an intense downdraft with strong surface wind outflows. They are particularly dangerous to landing or departing aircraft. The TDWR scanning strategy is optimized for microburst/wind shear detection. The radars are located near airport operating areas so as to provide the best scan of runways and the approach and departure corridors. System displays are located in the tower cab and Terminal Radar Approach Control Facility.

The Low Level Wind Shear Alert System (LLWAS) provides information on hazardous wind shear events that create unsafe conditions for aircraft land-

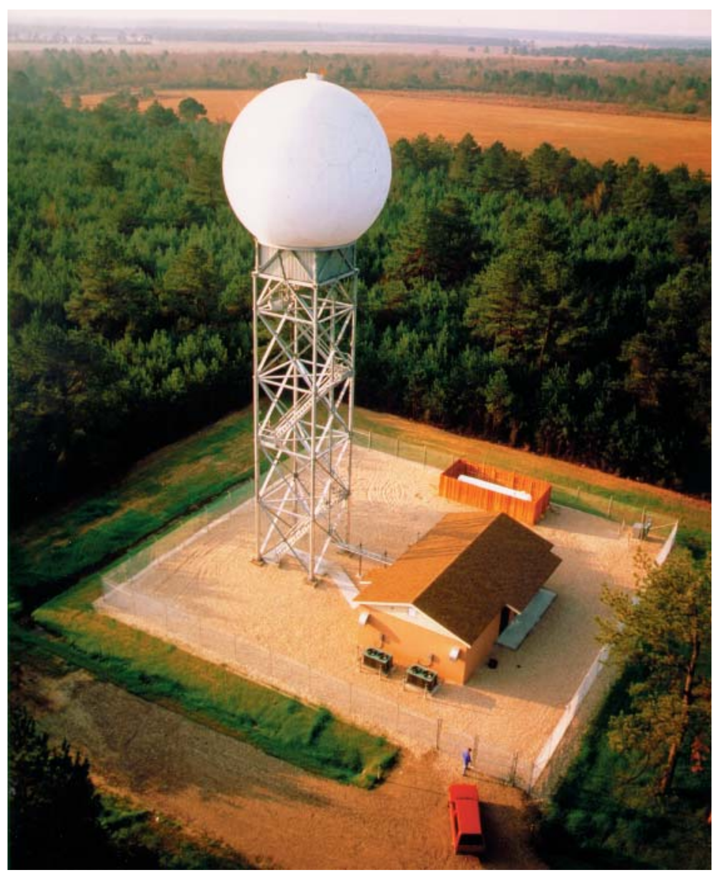
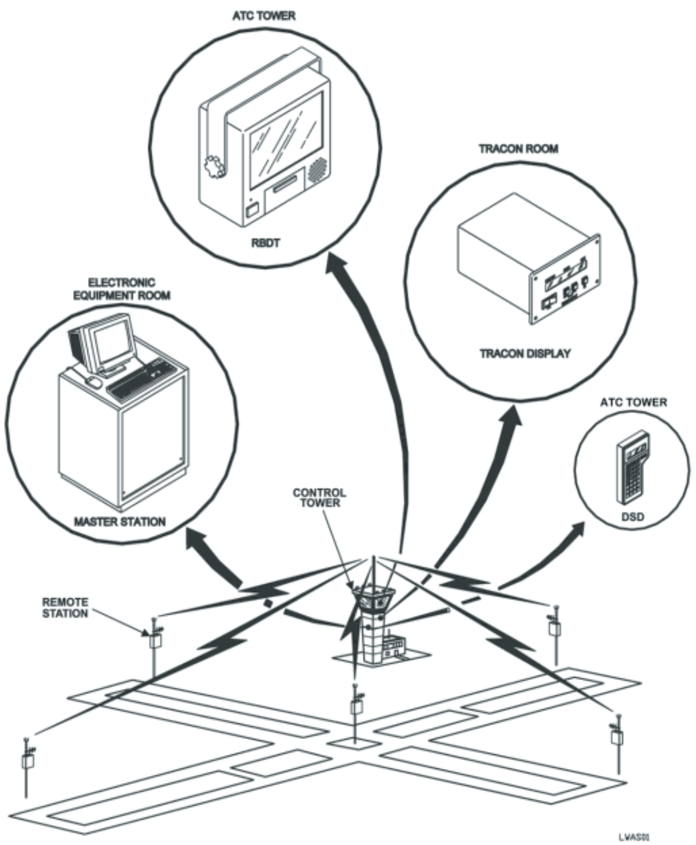


Figure 3-DOT-3. FAA Terminal Doppler Weather Radars provide supplementary wind and precipitation conditions for airport approach and departure.

Figure 3-DOT-4. LLWAS equipment on an airfield.




ings and departures. The 116 LLWAS-2 systems each consist of a wind sensor located at center field and 5 to 32 sensors located around the periphery of the airport (Figure 3-DOT-4). A computer processes the sensor information and displays wind shear conditions to air traffic controllers as a ribbon display. The controllers relay the information to pilots.

An improvement phase, referred to as LLWAS-Relocation/Sustainment (LLWAS-RS), was completed in FY 2008. For LLWAS-RS, the network of sensors was expanded and improved algorithms were developed for this expanded network. New information/alert displays enable controllers to provide pilots with head wind gain or loss estimates for specific runways. These improvements increase the system's wind shear detection capability and reduce false alarms. The LLWAS-RS improvements are also expected to reduce maintenance costs.

The Weather Systems Processor (WSP) program provides an additional radar channel for processing weather returns and de-aliasing returns from the other weather channel in the Airport Surveillance Radar 9 (ASR-9). The displays of convective weather, microburst, and other wind shear events from the WSP provide information for controllers and pilots to help aircraft avoid those hazards. All 34 WSP units are in place and operating, with an additional 5 support units. A technology refresh program has been approved for the WSP to refurbish and restock system parts, in order to extend system operability to beyond the year 2020 timeframe.

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. The TWIP capability, which is incorporated in the TDWR software application, provides pilots with information on regions of moderate to heavy precipitation, gust fronts, and microburst conditions. Text messages or character graphic depictions are received in the cockpit through the Aircraft Communication Addressing and Reporting System (ACARS) data link system. The TWIP capability is operational at most of the 49 operational, commissioned TDWR sites. Activation of TWIP at the remaining sites is dependent on availability of National Airspace Data Interchange Network (NADIN) II connectivity and program funding.

The FAA has installed Aviation Closed Circuit Television (CCTV) Weather Cameras as an aid to Visual Flight Rules (VFR) pilots operating in Alaska. Through the cameras and the Internet, pilots get a current picture of the weather conditions to assist them in making flight decisions. There are 84 weather CCTV camera sites, with an addition 10 requested for FY 2009.

The Juneau Airport Wind System (JAWS) is unique to the Juneau, Alaska, airport, which routinely experiences severe turbulence conditions. It is a prototype with a long development history. When operational, it will enable air traffic controllers to pass turbulence alerts to airline pilots and other users via the Automatic Terminal Information System (ATIS) and radio transmissions. It is also intended to enable Automated Flight Service Station (AFSS) Specialists to provide pertinent wind information to general aviation pilots on request during preflight and in-flight weather briefings and radio contacts.

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 with which airport operations are affected by weather.

Level D service is provided by a stand-alone Automated Surface Observing System (ASOS). Level D service is available at 439 airports.

Level C service includes the ASOS plus augmentation by tower personnel. Tower personnel add to the report their observations of thunderstorms, tornadoes, hail, tower visibility, volcanic ash, and virga when the tower is in operation. Level C service is available at 307 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, snow increasing rapidly remarks, thunderstorm/lightning location remarks, and remarks for observed significant weather not at the station. Level B service is available at 59 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 is available at 73 airports.

Automated surface aviation weather observing systems will provide aviation-critical weather data such as wind velocity, temperature, dew point, altimeter setting, cloud height, visibility, and precipitation type, occurrence, and accumulation. 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 SYSTEM (AWOS)

AWOS provides basic aviation weather observations 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. AWOS units 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. 168 AWOSs are fielded.

AUTOMATED SURFACE OBSERVING SYSTEMS (ASOS)

In a joint program with NOAA NWS, the FAA has procured and installed, and now operates, ASOS units at 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 580 systems installed and commissioned.

AVIATION WEATHER SENSOR SYSTEMS (AWSS)

The AWSS (Figure 3-DOT-5) has capability similar to ASOS. However, the AWSS is a direct acquisition of the FAA, rather than an acquisition through the joint ASOS program. Production and deployment of 21 AWSS units was completed in CY

Figure 3-DOT-5. Aviation Weather Sensor Systems (AWSS) an ASOS like supplement for observations.

2005.

AWOS/ASOS DATA ACQUISITION SYSTEM (ADAS)

ADAS functions primarily as a message concentrator. It collects weather messages from AWOS and ASOS equipment located at controlled and non-controlled airports within each Air Route Traffic Control Center's area of responsibility. ADAS distributes 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. Also, ADAS distributes AWOS data to the NADIN which in turn forwards the data to the Weather Message Switching Center Replacement (WMSCR) for further distribution. Field implementation of ADAS is complete.

AUTOMATED LIGHTNING DETECTION AND REPORTING SYSTEM (ALDARS)

ALDARS is a system adjunct to the ADAS. ALDARS collects lightning strike information from the National Lightning Detection Network and disseminates the data to AWOS/ASOS/AWSS for the inclusion of thunderstorms (when observed) in the METAR or SPECI observations ultimately produced by AWOS/ASOS/AWSS. The use of ALDARS eliminates the need for manual reporting of thunderstorms and increases the number of airports where thunderstorms will be reported. ALDARS is completely operational.

STAND ALONE WEATHER SENSORS (SAWS)

SAWS are back-up systems for some AWOS/ASOS sensors at locations where no other back-up capability is available. SAWS capability has been demonstrated, and 123 systems have been delivered.

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 regular maintenance. 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 the FAA Advisory Circular on Non-Federal Automated Weather Observing Systems. There are more than 580 non-Federal AWOS locations. Some of these are capable of reporting through a geostationary communications satellite. These observations will be entered into the national network for use in support of the NAS and the national weather network.

NEW GENERATION RUNWAY VISUAL RANGE (NRVR)

The NRVR program provides RVR information to controllers and users in support of precision landing and take-off operations. This new element in the NAS infrastructure incorporates state-of-the-art sensor technology and embedded remote maintenance monitoring. The FAA plans to procure and install NRVR systems at all new qualifying locations. FAA plans also call for the replacement of many existing RVR sensor systems in the NAS inventory.

The NRVR 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. Forward scatter meters will replace the transmissometers currently in use. A runway light intensity monitor reports on both runway edge and center-line lights. An ambient light sensor controls computer calculations using a day or night algorithm. The data processing unit calculates runway visibility products and distributes the products to controllers and other users.

NRVR visibility sensors will be deployed at 315 airports. Delivery of the NRVR sensors began in November 1998. To date, 249 units have been delivered and 232 have been commissioned. At the current levels of annual funding, deployment will be completed by the end of CY 2009.

OPERATIONAL AND SUPPORTABILITY IMPLEMENTATION SYSTEM (OASIS)

The FAA procured OASIS to improve weather products, flight information, aeronautical data collection, analysis, and timeliness of dissemination, thereby enhancing the safety and efficiency of the NAS. Seventeen systems have been deployed to FAA Flight Service Stations and Automated Flight Service Stations in Alaska. OASIS replaced the Model-1 Full Capacity Flight Service Automation System and. integrated the Interim Graphic Weather Display System functions. It includes several automated flight service data handling capabilities, automated special use airspace, and training support. OASIS supports flight planning, weather briefings, Notice to Airmen (NOTAM) service, search and rescue, and pilot access terminal services. OASIS procurement ended in FY 2008, but systems in place will continue operating beyond the 2012 timeframe.

NEXT GENERATION WEATHER RADAR (NEXRAD)

NEXRAD, known operationally as the Weather Surveillance Radar-1988 Doppler (WSR-88D), is the product of a multi-agency program that defined, developed, and implemented this weather radar. Field implementation began in 1990 and was completed in 1996 with 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 its improved detection capability for 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 continue to 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 Air Traffic Control through the WARP increase aviation safety and fuel efficiency.

The three NEXRAD funding agencies jointly 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.

AIR ROUTE SURVEILLANCE RADAR (ARSR-4)

The ARSR-4 provides the Air Route Traffic Control Centers with accurate multiple weather levels out to 200 nautical miles. The ARSR-4, which resulted from a project jointly funded by the FAA and the U.S. Air Force, was 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. Forty joint radar sites were installed during the 1992-1995 period.

WEATHER AND RADAR PROCESSOR (WARP)

WARP has replaced the Meteorologists Weather Processor to provide aviation weather information to the Center Weather Service Units. WARP automatically creates unique, regional, WSR-88D-based, mosaic products and sends these products, along with other time-critical weather information, to controllers through the Display System Replacement and to pilots via Flight Information Services. WARP greatly enhances the dissemination of aviation weather information throughout the NAS. It underwent operational testing and evaluation in early FY 2003 and is operationally fielded at the 21 Air Route Traffic Control Centers and the Air Traffic Control System Command Center. Others systems used for enhancements, testing, and software support bring the total WARP inventory to 25 systems.

DIRECT USER ACCESS TERMINAL (DUAT)

The DUAT system has been operational since February 1990. Through DUAT, pilots are able to access weather and NOTAMs, as well as file their IFR and/or VFR flight plans, from their home or office personal computer.

## AVIATION WEATHER COMMUNICATIONS

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

The National Airspace Data Interchange Network (NADIN II) packet-switched network was implemented to serve as the primary 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 that provides extremely high data flow capacity and efficiency to the network's 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. NADIN II interfaces directly to Weather Message Switching Center Replacement (WMSCR), WARP, ADAS, TMS, and the Consolidated NOTAM System. NADIN II is tentatively planned for decommissioning in the 2011 time frame and will be replaced by the FAA Telecommunications Interface (FTI).

The Weather Message Switching Center Replacement (WMSCR) replaced the Weather Message Switching Center (WMSC) located at FAA's National Communications Center (NATCOM), Kansas City, Missouri, with state-of-the-art technology. WMSCR is the primary NAS interface with the National Weather Service Telecommunications Gateway (NWSTG) for the exchange of aviation alphanumeric and limited gridded weather products. WMSCR collects, processes, stores, and disseminates aviation weather products to major NAS systems, the airlines, and international and commercial users. WMSCR also provides storage and distribution of domestic NOTAM data and retrieval of international NOTAMs through the Consolidated NOTAM System. WMSCR currently relies on NADIN II for the majority of its communications support and will transition along with NADIN II to FTI.

To provide for geographic redundancy, the system has nodes in the NADIN buildings in Atlanta and Salt Lake City. Each node supports approximately half of the United States and continuously exchanges information with the other node to ensure that both nodes have identical national databases. In the event of a nodal failure, the surviving node assumes responsibility for dissemination to the entire network.

Currently, specifications for an upgrade or replacement for the WMSCR are being formulated. WMSCR functionality will eventually be subsumed into System Wide Information Management (SWIM).

The World Area Forecast System (WAFS), compliant with ICAO Annex 3, produces flight planning products used in international air carrier operations. This system is composed of product generation and satellite distribution functions. The information and products are prepared at two World Area Forecast Centers (WAFC) designated as WAFC Washington, and WAFC London. The distribution is accomplished through three geosynchronous satellite broadcasts operated by the two WAFCs. Two of the three satellites are funded by the United States. The first is located over the western Atlantic with a footprint covering western Africa and Europe, the Atlantic Ocean, South America, and North America (except for the West Coast and Alaska). The second U.S.-funded satellite is positioned over the Pacific and covers the U.S. West Coast and Alaska, the Pacific Ocean, and the Pacific rim of Asia. A 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.

The System Wide Information Management (SWIM) is a new concept developed in conjunction with NextGen to support NAS operations starting in 2011 and eventually supporting the full deployment of NextGen. For NextGen, all weather data will be resident in a 4-D Weather Data Cube, which will be accessible to all users. Having this single authoritative data source will ensure that collaborative decision making in air traffic management will benefit from sharing a common situational awareness of current and forecast weather conditions.

## AVIATION WEATHER RESEARCH PROGRAM

The Aviation Weather Research Program (AWRP) helps achieve FAA's strategic goal of increasing aviation safety by reducing the number of accidents associated with hazardous weather conditions. The AWRP strives to increase capacity by reducing the impacts of adverse weather events on the operational capacity of the NAS. This research program also supports FAA Flight Plan goals for greater capacity. The AWRP is performing the research necessary to meet the requirements of the NextGen Integrated Work Plan. FAA collaborations with the NWS and NASA increase FAA's ability to provide improved short-term and mid-term forecasts of naturally occurring atmospheric hazards such as turbulence, severe convective activity, icing, and restricted visibility. Improved forecasts enhance flight safety, reduce air traffic controller and pilot workload, enable better flight planning, increase productivity, and enhance common situational awareness.

IN-FLIGHT ICING

This research is aimed at developing improvements to in-flight icing diagnosis, which includes detection and forecasting. The efforts support the NextGen Integrated Work Plan as well as icing forecast improvements as described in the FAA Aircraft Icing Plan. The current icing potential (CIP) and forecast icing potential (FIP) products have been developed to provide hourly updates of current and forecast conditions out to 12 hours. These products include severity and probability of icing conditions and supercooled liquid droplet potential. Planned efforts include expanding CIP and FIP to Alaska and globally (oceanic routes).

CONVECTIVE WEATHER

Research efforts for convective weather are targeted to developing an advanced storm prediction algorithm that enhances the production and capability of legacy storm products. These efforts will help mitigate convective weather delay and improve safety near thunderstorms. Fuzzy logic forecast technology, coupled with numerical weather predictions and climatology, is utilized to produce a blended 0-6 hour and beyond forecast. These forecasts will also enhance capability to predict growth, areal extent, movement, and type of precipitation. Probabilistic forecasts are also being developed to enable more effective traffic flow planning and more efficient use of the NAS.

MODEL DEVELOPMENT AND ENHANCEMENT

This research is targeted at developing or improving models to better characterize the state of the atmosphere, with the aim of providing superior aviation weather products to end users. A new higher-resolution (mesoscale) modeling system—the Weather Research and Forecasting Model (WRF)—has been under development to account for smaller-scale processes that are important to aviation weather but can only be approximated in the current Meso Eta and RUC models. WRF provides research-to-operations benefits: it offers operational forecasting a model that is flexible and efficient computationally, with advances in numerical weather prediction modeling contributed by the research community. The development of WRF has been a collaborative partnership of the FAA, NOAA, the National Center for Atmospheric Research, the Center for the Analysis and Prediction of Storms, the Air Force Weather Agency, and the Naval Research Laboratory.

TURBULENCE

This research has focused on producing a system for real-time turbulence nowcasts and 1-12 hour probabilistic forecasts of turbulence. The method utilized in meeting these objectives is a turbulence forecasting task in conjunction with two supporting sensor tasks, one for in-situ detection of turbulence, the second for remote sensing of turbulence. Research efforts to date have resulted in the Graphical Turbulence Guidance (GTG), the current version of which provides clear-air turbulence forecasts out to 12 hours for Flight Level 20,000 and above. GTG-2, the next version, will extend the forecasts down to Flight Level 10,000. GTG-2 forecasts are also more accurate due to the inclusion of objective turbulence measurements from an on-board algorithm. The remote sensing task has targeted the use of data from the NEXRAD radar network. Data from the NEXRAD Turbulence Detection Algorithm, currently operational on NEXRAD units, will be used to provide a GTG nowcast (GTG-N). In addition, GTG will be expanded to include all flight levels as well as other sources of turbulence such as mountain wave and convective turbulence. It will also provide probabilistic forecasts.

NATIONAL CEILING AND VISIBILITY

This research targets the use of observations, numerical modeling, and computer automation to solve key problems related to low ceilings and visibility. Capabilities are being developed that will display areas with low ceilings and visibilities and depict "flight categories" where weather that is hazardous can be expected. The new capabilities will include gridded analysis of current ceiling, visibility, and flight category conditions updated every 5 minutes and gridded 1-12 hour forecasts of ceiling, visibility, and flight category updated hourly. These capabilities, which are currently under development for the continental United States and are planned for Alaska, will reduce general aviation accidents and enhance terminal flow planning.

VOLCANIC ASH DISPERSION FORECASTS

Research efforts in this area target enhanced forecasts of volcanic ash dispersion for the FAA. The forecasting approach will employ automated satellite-based detection of volcanic ash plumes, with development of volcanic ash injection model parameters based on the use of satellite algorithms. The resultant forecast model, updated every 6 hours, will be transitioned to the Fleet Numerical Meteorology and Oceanography Center for operational implementation. Results will be disseminated as a decision support tool for air traffic controllers on the DOTS and ATOP systems.

QUALITY ASSESSMENT

This research team conducts verification and assessment activities to support all AWRP algorithm development activities and NextGen implementation. Quality Assessment evaluations of weather research capabilities use the Real-Time Verification System (RTVS). This system supports real-time forecast operations, development, and case study assessments. RTVS provides a mechanism for monitoring and tracking improvements to weather forecast products with an independent assessment of forecast quality. Its outputs are thus valuable as support for decisions on whether to move weather products into operations.

The Network-Enabled Verification Service (NEVS) is under development to replace the RTVS and support the NextGen initial operating capability. NEVS will provide an automated network-enabled web-based verification capability that is compatible with SWIM and NNEW architectures and with NextGen information delivery mechanisms.

ADVANCED WEATHER RADAR TECHNIQUES

This research is aimed at developing techniques for using weather radar data to improve weather forecasting. Information developed by these efforts is used by the other AWRP weather research teams to improve their forecast and nowcast products.

WEATHER TECHNOLOGY IN THE COCKPIT (WTIC)

The Weather Technology in the Cockpit (WTIC) program is a NextGen Research and Development program. Its objective is to ensure the adoption of cockpit, ground, and communication technologies, practices, and procedures that will provide pilots with shared and relevant weather information. Thus, it will enhance common situational awareness; provide airborne tools to exploit the common weather picture; and enable the use of “aircraft as a node” functions, through which aircraft autonomously exchange weather information with surrounding aircraft and ground systems. WTIC will facilitate integration of weather information into cockpit NextGen capabilities (e.g. Trajectory Based Operations), while also supporting certification, standards development, and operational approvals.

## THE ROAD WEATHER MANAGEMENT PROGRAM

The Federal Highway Administration (FHWA) coordinates a number of activities aimed at improving safety, mobility, productivity, environmental quality, and national security on the nation's highways during weather threats. These activities include identification of weather impacts on the roadway environment and traffic flow, and the operational decisions that are made because of them. It includes research to advance the state of the art concerning road weather management tools, as well as documentation and promotion of the best practices. The FHWA supports these activities through the Federal-Aid Highway program and by initiating national coordination efforts since it operates neither the highway system nor road weather observing systems that serve state and local highway operators, private road users, and the traveling public. The FHWA activities are conducted as partnerships with other public agencies, the private sector, and universities.

As of 1997, coordination of the FHWA's weather-related activities has been centered in the Road Weather Management Program (RWMP) within the Office of Transportation Operations. From the beginning, an important goal of this program has been to help promote road weather research and development. This objective and its associated roadmap were further defined in 2005 by the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Title V, Subtitle C - Intelligent Transportation System Research, Section 5308 of this bill contains specific reference to a "Road Weather Research and Development Program," the scope of which includes: maximizing the use of available road weather information and technologies; expanding road weather research and development efforts to enhance roadway safety, capacity, and efficiency; minimizing environmental impacts; and promoting technology transfer of effective road weather scientific and technological advances. The bill directs the Secretary of the U.S. DOT to carry out research and development called for in the National Research Council's (NRC) report entitled, Where the Weather Meets the Road, A Research Agenda for Improving Road Weather Services. This effort includes: integrating existing observational networks and data management systems for road weather applications; improving weather modeling capabilities and forecast tools, such as the road surface and atmospheric interface; enhancing mechanisms for communicating road weather information to users, such as transportation officials and the public; and integrating road weather technologies into an information infrastructure. The bill also includes three guiding principles which are to: enable efficient technology transfer; improve education and training of road weather information users, such as State and local transportation officials and private sector transportation contractors; and coordinate with transportation weather research program in other modes, such as aviation.

Funding authorized for Section 5308 is $5 million per year for the years 2006 to 2009, and the Secretary was directed to give preference to applications with significant matching funds from non-Federal sources. The FHWA Road Weather Management team is responsible for executing the program in coordination with the ITS Joint Program Office. The goals and objectives of the RWMP and its associated roadmap have been modified to align with the legislation, though such modification was minimal since the existing program already aligned very closely with the NRC report. Numerous efforts and initiatives within the RWMP are satisfying the requirements in the bill, including the Maintenance Decision Support System (MDSS), the Clarus initiative, and the Memorandum of Understanding between the FHWA and NOAA.

Some of the activities occurring within the RWMP include:

<u>The Strategic Highway Research Program (SHRP)</u>

Congress established the Strategic Highway Research Program (SHRP) under the 1987 Surface Transportation Act. SHRP examined a number of different subject areas including winter maintenance operations on the nation's highways. The research program was active until 1993, producing specifications, testing methods, equipment, and advanced technologies. Following the success of the five-year effort, the FHWA coordinated a national program, entitled SHRP Implementation, to work with state and local highway agencies to implement and evaluate the products. The American Association of State Highway and Transportation Officials (AASHTO) and the Transportation Research Board (TRB) administered this program in coordination with FHWA. The SHRP Implementation web site (www4.trb.org /trb/dive.nsf/web/shrp_implementation) contains information on the SHRP Lead States Program, SHRP products under evaluation and implementation, and SHRP in general.

The Intelligent Transportation Systems (ITS) Program

The Intermodal Surface Transportation Efficiency Act of 1991 established the ITS Program, including its research program that funds the FHWA Road Weather Management Program activities. This program is overseen by the ITS Joint Program Office (ITS-JPO), which is a cross-modal office hosted in the Research and Innovative Technology Administration. While ITS initially focused on automated highways and metropolitan areas, a rural focus was initiated in 1996. The rural ITS program identified maintenance and weather as additional ITS focus areas, and recognized the need for total integration of the maintenance, traffic, and emergency management functions across wide areas and between states. The following research activities are examples that fall within this overall weather-across-ITS strategy:

Vehicle Infrastructure Integration (VII) Initiative

This initiative (www.its.dot.gov /vii/index.htm) is exploring the potential of creating a data sharing communication system that can support vehicle-to-vehicle and vehicle-to-infrastructure communications. The system, once implemented, will be able to provide real-time travel and weather information to both the public sector and private industry by using vehicle-based sensors to gather a variety of data system-wide. This resulting communications network would allow weather, traffic, and other information to be transmitted to transportation operators, providing a real-time view of the conditions on every major road within the transportation network. Such concepts will be explored as the initiative matures. Preliminary documentation describes some of the weather-related data items that could be directly measured or inferred from vehicle sensor systems including precipitation detection, ambient air temperature, fog or visibility information, and road traction state or mobility. The RWMP has sponsored a feasibility study to explore and assess the utility of using data from vehicles to improve surface transportation weather observations and predictions. As the functional architecture and requirements for VII are developed, the RWMP ensures that surface transportation weather applications are considered. As VII operational tests take place (e.g., in Michigan, California and New York), the RWMP will utilize data collected during these demonstrations to address technical issues and challenges related to the use of vehicle data, and provide recommendations that will help ensure successful exploitation of vehicle probe data in weather applications.

National ITS Architecture and ITS Standards

Intelligent Transportation Systems use open system principles and are based upon the National ITS Architecture - a modularly defined set of information processes with known protocols for exchanging information between modules. While road weather information was not an original focus of the National ITS Architecture, it has since been captured through the Maintenance and Construction Operations (MCO) user service. MCO development included the definition of a Road Weather Information Service terminator designed to complement the existing Weather Service terminator. Together, these represent the division of responsibility for road weather information, provided largely by private vendors and based on ESS observations, and weather information in general. The interfaces between the two types of services are then defined as being outside of the ITS, although the FHWA continues to maintain an active interest in their development.

It is hoped that further detailing of weather applications in traffic and emergency management will lead to further architecture developments in the years ahead. As the interface between the ITS and evolving national weather information systems becomes better defined, the National ITS Architecture and standards will provide a technical basis for integration and promotion of open system principles. Version 6.0 of the National ITS Architecture can be found at http://www.iteris.com/itsarch/.

Road Weather Observing Systems

Road weather observing systems are known as Environmental Sensor Stations (ESS). Nearly 2,500 ESS are owned by state transportation agencies in the United States as shown in Figure 3-DOT-8. More than 2,000 of these ESS are field components of Road Weather Information Systems. Most of the ESS that are placed in the field are fixed and tend to include in situ sensors for the most common atmospheric weather variables as well as pavement and subsurface temperature probes, pavement chemical concentration and/or pavement freezing point. A growing trend is the use of mobile environmental sensors that are being deployed to observe weather and pavement conditions from vehicles. An important application of the mobile (and potentially remote) sensing is thermal mapping of road segments. This technique provides snapshots of complete pavement temperature profiles which can then be used to select fixed optimal ESS sites and to spatially predict temperatures based on time series predictors at the fixed stations. Research funded by the FHWA has also investigating the potential to extract surface weather and road condition data from standard traffic camera imagery. The potential value of this research is significant considering the fact that in 2006, there were over 7,000 Closed Circuit Television (CCTV) traffic cameras deployed nationwide.

At present, ESS data from across the United States has never been collected, formatted and quality checked in a uniform manner at the national level. Nor has it then been made, available to all users from a "one-stop-shop" location so that it can be more effectively utilized by members of both the weather enterprise and the transportation community. A U.S. DOT-sponsored initiative entitled Clarus aims to correct this shortfall by designing and demonstrating an integrated road weather observational network, and establishing a partnership to facilitate operation of a nationwide surface transportation weather observing system. The long-term vision of Clarus is that all data from State DOT ESS will be routinely collected, quality-checked, and translated into an open standard format. Quality checking algorithms and direct feedback to state DOT points of contact will improve agency awareness of sensor status. Access to robust and calibrated data will be provided through an open Internet data portal. The Clarus Concept of Operations and the Clarus system design has been completed. A Proof-of-Concept demonstration occurred in 2006,

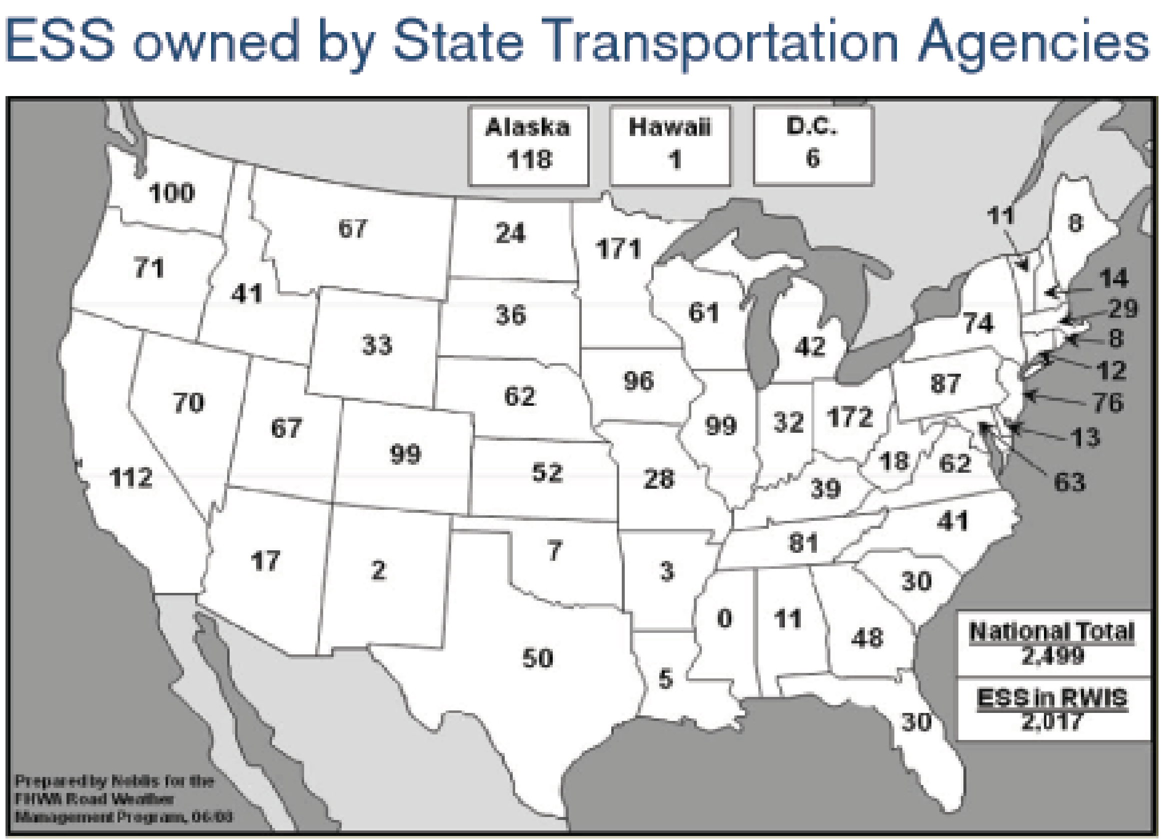



Figure 3-DOT-2. Census of Deployed Environmental Sensor Station (ESS) Units.

and regional demonstrations were initiated in 2007. In phase one of the Clarus Multi-state Regional Demonstrations, three teams of state and provincial DOTs identified their needs for new products, tools and services in Concepts of Operations documents. Phase two is a Connection Incentive Program that provides grants to public transportation agencies to assist them in connecting to the Clarus System. The third phase of the demonstrations will begin in fall 2008 and focus on development, deployment, and evaluation of Clarus-enabled services based on the needs documented in the phase one Concepts of Operations. The RWMP has worked closely with NOAA to ensure that the experimental Clarus System can be transitioned into the National Weather Service at the conclusion of the Clarus Multi-state Regional Demonstrations.

In order to address some of the issues related to surface weather observations, the FHWA is participating in several OFCM projects including the WIST Working Group, the Phased Array Radar (PAR) Joint Action Group, the Joint Action Group for Joint Urban Test Beds (JAG/JUTB), the Fire-Weather Joint Action Group, the Joint Action Group for Severe Local Storm Operations (JAG/SLSO), the Ground Deicing Weather Subcommittee, the Committee on Environmental Information Systems and Communication, and the Committee for Environmental Services, Operations, and Research Needs (CESORN). The FHWA is also participating in NOAA efforts to explore the modernization of the cooperative observer network and development of a national surface weather observing system.

From 2001 to 2003, the FHWA sponsored five research projects, under the Cooperative Program for Meteorological Education and Training (COMET) (www.comet.ucar.edu), which became the first to add state DOTs to the traditional partnerships of NWS forecast offices and universities. The COMET projects in Iowa, Nevada, New York, Pennsylvania, and Utah fostered the sharing of environmental data and facilitated advanced meteorological modeling to enhance road weather forecasts. Ultimately, these efforts will contribute to the development of decision support tools for winter maintenance managers, traffic managers, and the traveling public. Lessons learned from these projects can help all state DOTs better manage RWIS networks and achieve maximum utility from RWIS data.

In order to enhance observation capabilities and define requirements for road weather observing systems, the Road Weather Management Program worked with the Aurora Pooled Fund Program and the AASHTO Snow and Ice Cooperative Program to produce the Road Weather Information System ESS Siting Guidelines (http://ops.fhwa.dot.gov/publications/e ss05/). The guidelines, published in 2005, provide a set of recommendations to support uniform siting of ESS that collect road and weather observations for RWIS, and are intended to improve the usefulness of road weather information derived from these observations. In 2006, the Road Weather Management Program initiated a project to implement and evaluate the guidelines in a field environment to ensure that the recommendations are realistic and that the guide is useful to State DOT deployers. The results of this study will be used to refine the guidelines as necessary.

Decision Support

Transportation system managers and users identify three critical surface weather information requirements as the trinity of "relevance, accuracy and timeliness". Although significant progress continues to be made by both the public and private sectors in providing new technologies to meet these requirements, a significant gap has developed between the amount of increasingly good and plentiful surface weather information, and the amount of support available for effective operational decision making. Assisting and supporting the research and development of techniques to overcome this gap has become an important initiative within the FHWA.

Decision support is where surface weather data needs to be customized since each operational decision is specific to a type of road weather management strategy, a particular place and time, and the characteristics of the decision-maker (their expertise, their location, their information processing equipment). Road weather management strategies mitigate weather impacts by advising motorists of prevailing and predicted conditions (e.g., traveler information), controlling traffic flow and roadway capacity (e.g., weather-responsive traffic signal timing, road closure), and/or treating roads to minimize or eliminate weather threats (e.g., plowing, anti-icing/

deicing).

In 1999 and 2000, decision support requirements, first generally and then specifically for winter road maintenance, were studied in the Surface Transportation Weather Decision Support Requirements (STWDSR) project. This project used weather threat scenarios to identify specific decisions made in winter road maintenance, their timing, and the expected confidence of the decisions at various time horizons. General requirements for emergency managers, traffic managers, and road users were also defined. The STWDSR project became an important contributor to the OFCM's Weather Information for Surface Transportation (WIST) needs analysis, the National ITS Architecture modifications, and to the Maintenance Decision Support System (MDSS) prototype project.

Along with the Maintenance Decision Support System described below, in 2006, the FHWA and the Missouri DOT developed and tested a prototype Weather Response System (WRS) for transportation system operations. The WRS used road weather information from the NWS, and other sources to support transportation control, maintenance and operations decision making. The results of the prototype testing and evaluation are being used to develop the concept of operations for a Maintenance and Operations Decision-Support System (MODSS) that expands the capabilities of MDSS for road maintenance beyond snow and ice control as well as into traffic management decision making.

Support for Maintenance Managers

The Maintenance Decision Support System (MDSS) project is a multiyear, FHWA-sponsored effort that was envisioned to assist transportation managers and operators improve roadway levels of service during winter weather events while minimizing road treatment costs (e.g., by optimizing use of labor, materials, and equipment). This data management tool has an ensemble of advanced weather prediction and road condition prediction capabilities, including air and pavement temperatures, precipitation start/stop times, precipitation types and accumulation amounts. These predictions are fused with customized winter road maintenance rules of practice to generate route-specific treatment recommendations (i.e., strategy, timing, and material application rates).

In the spring of 2003, the first functional MDSS prototype was demonstrated and evaluated by three Iowa DOT maintenance garages. The main display of the demonstration prototype, shown in Figure 3-DOT-9, includes predicted weather and road conditions, a weather parameter selection menu, a map of roads and weather alerts, as well as forecast animation controls. During the winter of 2004-2005, the demonstration domain was moved to Colorado to assess prototype capabilities over more complex terrain. Based on lessons learned from the preliminary demonstration in Iowa, the subsequent releases of Versions 2.0 and 3.0 in 2003 and 2004 respectively, and the Colorado demonstration, Version 4.0 was made available in November 2005. Lessons learned, recommended enhancements and the future directions of the program were addressed and discussed during the 8th and 9th annual stakeholder meetings in August 2006 and September 2007, and Version 5.0 was released in 2007.

In recognition of the progress being made in the development of a MDSS, the American Association of State Highway and Transportation Officials (AASHTO) Technology Implementation Group (TIG) proclaimed it to be a "2006 ready-to-implement technology" (AASHTO Journal 4/7/2006), and receiving this important designation facilitated increased deployment of this tool. In addition, the FHWA and its partners have worked together to ensure that the MDSS project evolves from prototype development to proactive outreach, deployment assistance, technology transfer, and expansion of functionality to other applications, such as non-winter road maintenance and traffic management, and even other surface transportation sectors. This change is consistent with the FHWA's original deployment strategy, which included creating an environment that enables the private sector to build end-to-end products using core MDSS prototype functionality/technology as their foundation. These products will be procured by public agencies (e.g., state DOTs), enabling both the private and public sectors to benefit from millions of dollars of high-risk research. One example of technology transfer is the MDSS Pooled Fund Study project led by the South Dakota DOT. Other participants include the state DOTs in California, Colorado, Indiana, Iowa, Kansas, Kentucky, Minnesota, Nebraska, New Hampshire, New York, North Dakota, Virginia, and Wyoming as well as Aurora (a pooled fund research program), a private vendor, and the FHWA. The objective of the project has been to build, evaluate, and deploy an operational MDSS by refining model components and conducting extensive field tests.

An example of proactive outreach has been the development and deployment of the "MDSS RoadShow" by the FHWA Resource Center. This free seminar, which includes both an Executive Briefing and a Shop Session, is available to transportation managers, maintenance engineers and operators. The presentation describes the functions of MDSS, its capabilities, and its limitations. It also provides a level of detail that helps public agencies make more informed decisions about investing in such a tool. In addition to the RoadShows, the FHWA has worked with partners to develop a free MDSS Product Demonstration Showcase. The Showcase will provide a neutral information exchange environment that provides an opportunity for transportation agency decision-makers to gain practical, unbiased, well-rounded, hands-on experience with new and proven products and services. The first of three MDSS Showcases took place in Omaha, Nebraska in May 2008.

Other recent FHWA-sponsored support activities included: updating several components of the MDSS core system; overseeing the release of an enhanced version of the software; conducting several benefit/cost analyses to generate quantitative results that can be used by the transportation community to justify investments in MDSS, and furthering the expansion of MDSS to MODSS (Maintenance and Operations Decision Support System) to include non-winter road maintenance and traffic management modules. Results of two stakeholders meetings that were held in February of 2007 will be used to initiate the development of these modules. Additional information on the MDSS project, the RoadShow, and the Product Demonstration Showcase can be found at www.rap.ucar.edu /projects/rdwx_mdss, at http://ops.fhwa.dot.gov/Weather/index.asp, and at http://www.ops.fhwa.dot.gov/weather/mitigating_impacts/mdss/showcase/index.htm; respectively.

Support for Traffic Managers

In 2006, the Road Weather Management Program developed a five-year roadmap for Weather-Responsive Traffic Management. The roadmap identifies the goals and activities that FHWA will pursue in three major program areas: data collection and integration, impacts of weather on traffic flow, and traffic management strategies. The roadmap also serves as the basis for future work to identify, develop, test, and evaluate a variety of weather-responsive traffic management strategies.

Empirical studies of traffic flow in inclement weather were completed in early 2007. This study developed adjustment factors for traffic parameters including speed and capacity as a function of precipitation and visibility. A follow-up research project on driver behavior in inclement weather was initiated in late 2007. This research will improve the understanding of how traffic flow and driver behavior change under adverse weather conditions. Once these factors are better understood, the information can be incorporated into traffic simulation models and, ultimately, traffic information and control tools. Also in 2007, the RWMP began a project to develop weather-sensitive traffic prediction and estimation models, and incorporate them into existing Traffic Estimation and Prediction Systems. Significant improvements in traffic estimation/prediction capabilities and overall utilities of these systems for traffic control and management can be achieved by upgrading or adjusting them to account for the impacts of weather.

511 - The National Traveler Information Telephone Number

Based on the concept that a standardized number for travel information would be beneficial to the traveling public, a broad coalition of ITS interests worked together to allocate a national 511 traveler information telephone number. In 2002, the FHWA sponsored a number of grants to plan for state deployment of 511 services, and guidelines were issued on service content. A survey on traveler information conducted by ITS America indicated that weather and road condition information were highest in demand by travelers, and therefore, this type of information is considered a key component of 511 services. The means of delivering this information through 511 continue to be developed, including ways to serve peak demands for emergency evacuation information, as part of the homeland defense, or other threat response capabilities.

In June 2003, the 511 Deployment Coalition released a Deployment Assistance Report, Weather and Environmental Content on 511 Systems, to recommend basic content and provide for consistency in 511 systems as they are deployed across the country. Since these systems are still relatively new, gaps exist in defining the types of road weather information travelers' desire, appropriate data formats, and the frequency and detail needed for travelers to make safe and effective decisions.

The Road Weather Management Program has participated in several 511 Deployment conferences and it continues its efforts to help establish road weather data requirements that can help to close these gaps. The 511 program is also exploring various ways to complement the NOAA Weather Radio broadcasts, and incorporate the NWS's official watches and warning information. The deployment of the 511 system is just one more way in which ITS is becoming a significant means for disseminating road weather information. In 2008, 511 services will be accessible to approximately 65 percent of our nation's population (Figure 3-DOT-10). More information can be obtained on the 511 system and the status of its deployment by visiting http://www.deploy511.org.

*Weather Impacts on Roadway Safety, Mobility & Productivity*

While the impacts and associated costs of adverse weather on surface transportation are considered to be immense, it has been difficult to quantify specific costs related to these impacts. This is also true of the benefits (as avoidable costs) that are achieved through better information that helps support more effective responses and/or mitigation strategies. It is likely that the costs to mobility, in terms of delay due to weather, are the most significant part of this economic picture. For example, initial estimates of the economic impact of weather-related delay to trucking companies ranges from 2.2 billion dollars to 3.5 billion dollars annually. The estimated cost of weather-related delay to trucking companies ranges from 2.2 billion dollars to 3.5 billion dollars annually. It has been estimated that 23 percent of the non-recurrent delay on highways across the nation is due to snow, ice, and fog. This amounts to an estimated 544 million vehicle-hours of delay per year. Rain–which occurs more frequently than snow, ice, and fog–leads to greater delay.

In an attempt to get a better understanding on the relationship between adverse weather and traffic delays, the FHWA sponsored a series of analyses that were conducted for the Seattle, Washington and Washington, D.C. metropolitan areas. These analyses combined surface weather observations with traffic speed data, both empirical and modeled. The results were consistent in showing about a 12 percent increase in travel time averaged over a wide range of weather events. A second analysis of delay effects in Washington, D.C. was conducted with archived Doppler radar data for more precise and more dynamic inference of road weather conditions. Analysis results indicated that during peak travel periods, travel time increased by roughly 24 percent when precipitation was present. It is the FHWA's belief, that achieving a better understanding of weather-traffic interactions, will lead to an improved ability to mitigate the impact of weather-related delays through traffic management practices, including speed management, access control (e.g., road closure), motorist warning systems, and weather-responsive signal timing.

<u>Road Weather Management Program Outreach and Training</u>

The Road Weather Management Program web site (www.ops.fhwa.dot.gov/weather) contains a wealth of information on the program. This includes details on objectives and initiatives, weather impacts, benefits of road weather management strategies, technologies to help mitigate weather impacts, training, upcoming events, a listing of over 600 road weather related publications, and 30 case studies highlighting road weather management best practices. Each case study describes has six sections including a general description of the system, system components, operational procedures, benefits (i.e., improved safety, mobility and/or productivity), implementation issues, as well as contact information and references.

A key outreach activity of the program is the annual “Eastern Snow Show” (formerly known as the Snow Expo). Over the past thirteen years, the FHWA has partnered with state agencies to host the Eastern Snow Show, which provides a forum for sharing information and technologies used to counter the effects of winter weather. AASHTO is now the lead sponsor, with the FHWA supporting this event as a co-sponsor. More information on the 2008 Eastern Snow Show can be found at www.transportation.org/meetings/178.aspx.

The FHWA sponsors training programs and conducts outreach to promote Road Weather Management Program products and activities. In 2005, a one-day training course on “Principles and Tools for Road Weather Management” became available through the National Highway Institute (NHI course No. 137030A). The course is aimed at helping those involved in highway maintenance and operations develop techniques and strategies for tackling road weather problems. The course provides basic knowledge of meteorology and addresses the technological resources available to support highway personnel in making effective road weather management decisions. The course was already delivered three times, and web-based versions were developed (additional details are listed on National Highway Institute web site (www.nhi.fhwa.dot.gov)).

The U.S. DOT, in coordination with ITS America, develop a complementary course entitled, Road Weather Information Systems Equipment and Operations. This course provides field and management staff with the basic knowledge and skills necessary for RWIS design, deployment, and operations. This course is available through the Rocky Mountain chapter of ITS America (http://www.itsrm.org).

In 2008, two new computer-based training courses were developed. The first course was developed by the Cooperative Program for Operational Meteorology, Education and Training (COMET), and it instructs public transportation managers and operators about NWS products and services, enabling them to make the best use of the extensive resources available. The second course is the converse, teaching forecasters at the NWS forecast offices about the needs and challenges of public transportation agencies (e.g., State DOTs). Arrangements to access these courses are in process.

The computer-based Anti-Icing/RWIS Training Program is a comprehensive, interactive training program for winter operations that was jointly developed by AASHTO, with support from the FHWA and Aurora. The training program covers an introduction to anti-icing and winter maintenance, winter road maintenance management, winter roadway hazards and principles of overcoming them, weather basics, weather and roadway monitoring for anti-icing decisions, computer access to road weather information, and anti-icing practice in winter maintenance operations. Additional details can be found on the American Public Works Association web site (http://www.apwa.net/bookstore/detail.asp?PC=PB.X407).

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.

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. 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 is one of the partnership initiatives identified in the National Science and Technology Council's National Transportation Technology Plan.

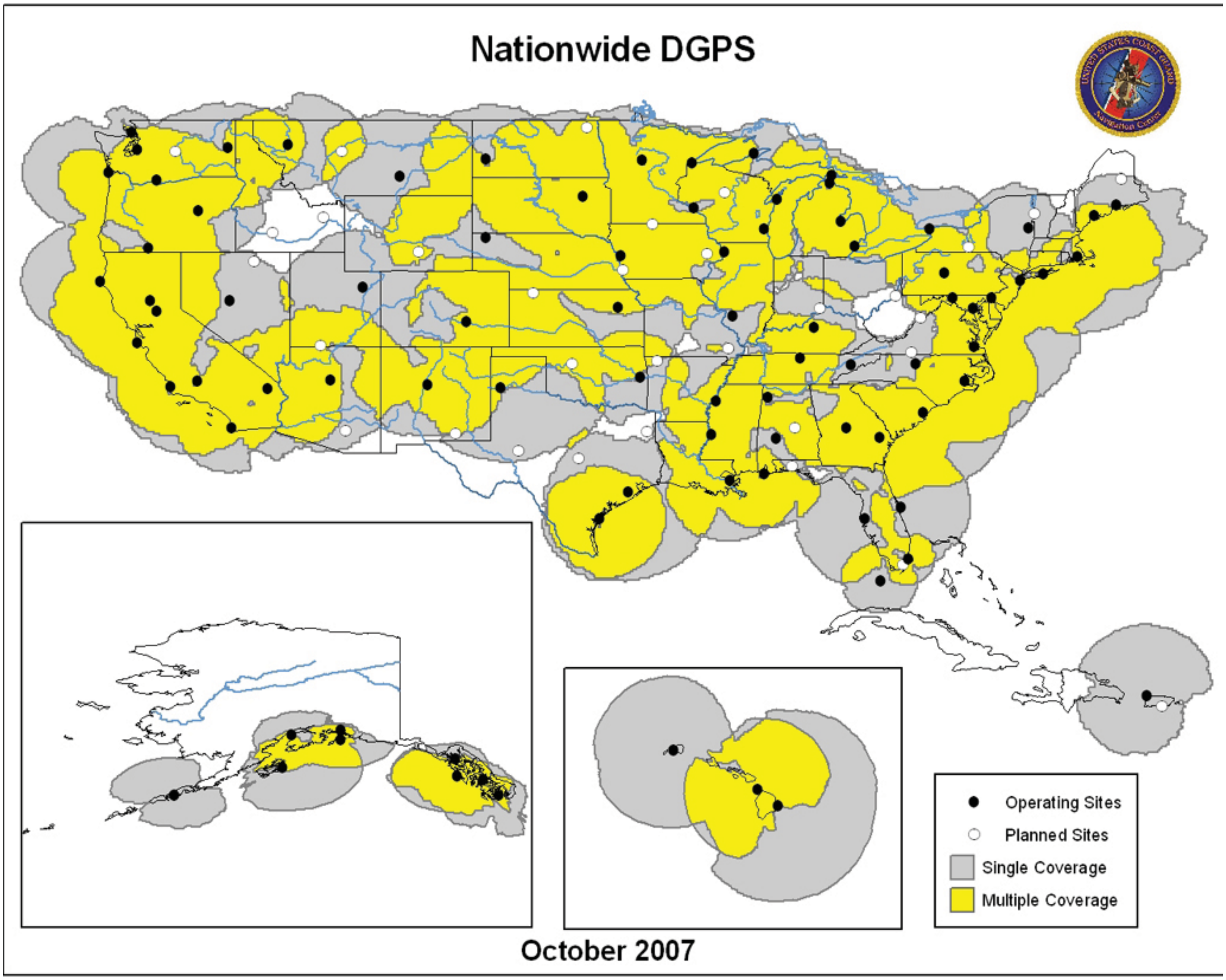
## WEATHER FORECASTING ENHANCED BY NATIONWIDE DIFFERENTIAL GLOBAL POSITIONING SYSTEMS (NDGPS)

NDGPS is a system of reference stations that monitors GPS and broadcasts corrections, which can be used by the GPS receiver to improve the accuracy, integrity and availability of the GPS position. The NDGPS program was transferred from FRA to DOT's Research and Innovative Technology Administration in Oct 07 and planning continues for expansion of the network as of August 2008. DOT's sites are operated and maintained by the US Coast Guard. NDPS is used in a myriad of applications including: maritime navigation, positive train control, precision farming, dredging, graphic information systems and surveying. Several agencies participate in the NDGPS project including the U.S. Air Force, the U.S. Army Corps of Engineers, the Federal Highway Administration, and the National Oceanic and Atmospheric Administration (NOAA).

The Global Systems Division (GSD) of the Earth System Research Laboratory (ESRL) of NOAA developed a unique meteorological application, which very accurately measures the amount of water vapor in the atmosphere by taking advantage of the dual-frequencies, reference station receivers at the NDGPS sites and a suite of weather sensors added to each reference station. The weather sensors measure temperature, relative humidity and barometric pressure. The GPS satellites broadcast on two frequencies, L1 and L2. GSD uses these two frequencies to correct for the ionospheric delay that is caused by changes in the refractive index associated with the concentration of free electrons in the upper atmosphere. The ionospheric delay is usually about 6-10 times greater than the signal delay caused by the neutral, non-electrically conducting, atmosphere. GSD can than estimate the signal delays caused by the neutral atmosphere by comparing the errors in position between sites that are over 500 km apart by viewing the same satellites for about 30 minutes. Most of the delay in the troposphere (lower atmosphere) is caused by the mass of the atmosphere, or the hydrostatic component, while the induced dipole moment of the water vapor molecules in the atmosphere is responsible for the rest of the delay.

The GSD can accurately estimate the hydrostatic delay by putting a pressure sensor at the NDGPS site and mapping the surface pressure into signal delay using well-known physical relationships. Subtracting the hydrostatic delay from the observed tropospheric delay gives the wet signal delay caused by water vapor in the atmosphere. Then, the wet delay is mapped into the quantity of water vapor responsible for the delay using information about the temperature of the atmosphere and the characteris-

Figure 3-DOT-3. National Differential Global Positioning Systems (NDGPS)




tics of the air at microwave frequencies.

This results in the equivalent height of a column of water that would form if all of the water vapor in the atmosphere were to fall or precipitate. The total precipitable water vapor content is a direct measure of how much raw material is in the atmosphere in the form of rain, snow, hail and clouds. As the water vapor changes state from gas to liquid to solid and back again, it releases or absorbs energy associated with the latent heat bound-up in the molecules. This energy release and absorption is the primary energy responsible for weather. The reason that water vapor is hard to measure is that it only manifests itself when it changes state, and most instruments that can observe water in its gaseous state do not work well under all weather conditions. However, NDGPS works remarkably well in all weather conditions. Water vapor is the most important component of weather and the least observed. In June 2005, the research and development program to evaluate the use of NDGPS data became an operational program feeding near-real time date into NOAA's operational models. The addition of this data has greatly improved the model and short-term weather forecasts, especially during periods of active weather such as fronts, hurricanes or tornadoes.

# ENVIRONMENTAL PROTECTION AGENCY WEATHER PROGRAMS

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 and meteorological programs to support regulatory applications. Applied research and meteorological support are furnished primarily by EPA's National Exposure Research Laboratory and EPA's 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 assigns approximately 50 research meteorologists to the EPA.

Meteorological support to EPA's Office of Research and Development, EPA's Office of Air and Radiation, EPA Regional Offices, and to state and local agencies includes:

- Development and application of multi-scale and multipollutant air quality models for pollution control, direct and indirect exposure assessments, and emission control strategy assessment;
- Preparation and performance of dispersion studies and air quality model evaluations;
- Review of meteorological aspects of environmental impact statements, state implementation plans, and pollution variance reques;
- Understanding the interactions of global climate change and air quality; and
- Emergency response planning in support of homeland security.

Meteorological expertise and guidance are also provided for the national air quality standards, modeling guideline, and policy development activities of the EPA.

In light of the 1990 Amendments to the Clean Air Act and the recent national rules, air quality models and the manner in which they are used are expected to continue to grow 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, aerosols, 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 new 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 the fine particulate model development, air quality models are being enhanced to accurately predict aerosol growth from precursors over local and regional-scale 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 emission sources can be discerned.

Atmospheric research is the area of the effects of climate change on regional air quality involves both analytical and statistical climatology as well as linking global climate models with regional chemical transport models, and the development of coupled models to better simulate the interactions between meteorlogy and atmospheric chemistry.

Research in human exposure modeling includes micro-environmental monitoring and modeling, and development of exposure assessment tools. This research entails linking air quality models to exposure models to understand the relationships between air quality and human health. Micro-environmental 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 micro-environmental simulation models for conducting human exposure assessments within enclosed spaces in which specific human activities occur.

In addition to the above 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, regional, and global. Other efforts include modeling nutrient deposition to Chesapeake Bay and mercury deposition to the Florida Everglades; and determination of meteorological effects on air quality. Atmospheric flow and dispersion experimental data obtained from wind tunnel and convection tank experiments in the EPA Fluid Modeling Facility will be used to continue development and evaluation of these models along with providing researchers with insight into the basic physical processes that affect pollutant dispersion around natural and man-made obstacles. For example, the transport and dispersion of airborne agents in the Manhattan, New York area were simulated in the wind tunnel to evaluate Computational Fluid Dynamics modeling systems in an effort to help build confidence in modeling assessment source-receptor relationships for horrific events such as the one that occurred on September 11, 2001. A similar study was conducted for the Pentagon and will be conducted for the Washington, DC area. The impacts of noise barriers and vegetation on air quality near roadways are being assessed and improvements are being made to better simulate the transport and dispersion of pollutants released from roadways.

Over the past twenty-five years, numerous air quality simulation models have been developed to estimate reductions in ambient air pollutant concentrations 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, spatially/temporally in the atmosphere. The principal purpose of the 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 CMAQ model was first released in June 1998, and is being updated periodically, reflecting the state-of-science, for use by Federal and state agencies, industry, and academia. The latest version of CMAQ, which includes science enhancements and computational efficiencies, will be released in September 2008. It is also intended to serve as a community framework for continual advancement and use of environmental assessment tools. 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. Additional information is available at the Division web site at http://www.epa.gov/asmdnerl/models3/.

In FY 2005, EPA worked closely with the National Center for Environmental Prediction of the National Weather Service (NWS) in the continued development, evaluation, and use of a coupled meteorological-chemical transport model (WRF-CMAQ) for predicting ambient air quality over the Continental United States. This capability is built on years of research in air quality, exemplified by the NOAA-led New England Pilot Air Quality Study in 2002 and 2004. In the first phase of the forecasting project, NWS implemented the Eta-CMAQ modeling system, to provide daily forecast guidance for ozone for the northeastern United States starting from September 2004. In 2007, the forecast system for ozone was deployed nationwide. In the next few years, the operational forecast capability is projected to be able to forecast fine particulate matter. State and local air quality management agencies will continue to forecast local air quality, assisted in their efforts by the addition of national forecast guidance for the concentrations of ozone and fine particles.

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). 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 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:

- Developing a prototype multiscale integrated modeling system with predictive meteorological capability for transport and fate of nutrients and chemical stressors;
- Enabling the use of remotely sensed meteorological data; and
- 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. 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 and spatially-explicit watershed modeling tools; and model-coupling technology for integrating media and scale-specific models.

EPA also maintains good working relationships with foreign countries to facilitate exchange of research meteorologists and research results pertaining to meteorological aspects of air pollution. For example, agreements are currently in place with Canada, UK, Greece, Japan, Korea, China, India, and Mexico, and with several European countries under the NATO Committee for Science for Peace (SPS).

# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WEATHER PROGRAMS

The National Aeronautics and Space Administration (NASA) supports weather operations through the Space Operations Mission Directorate (SOMD), weather and climate research through the Science Mission Directorate's (SMD) Earth Science Division, and space weather research through SMD's Heliophysics Division. The SOMD objective is weather-related safety of manned spacecraft, satellites, scientific instruments, and launch vehicles. The greatest challenge is to accurately measure and forecast mesoscale weather events that strongly impact ground processing, launch, and landing operations. The SMD objective is to improve accuracy of operational numerical weather prediction of severe storms through understanding of severe storm formation and subsequent trajectory and intensity. The greatest challenge is to observe the continuum of weather-to-climate processes and produce models verifiable with observations. The SMD objective in space weather research is to develop the scientific foundation that will enable space weather forecasters to predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers.

## OPERATIONS

### Kennedy Space Center Weather Office

The SOMD Weather Office at NASA Kennedy Space Center (KSCWO) has oversight responsibility for operation and maintenance of the weather information infrastructure required for NASA's Space Shuttle, Constellation, and Expendable Launch Vehicles (ELV) programs. The infrastructure is a multi-agency partnership of KSCWO, NASA Marshall Space Flight Center (MSFC), Department of Defense (DoD) U.S. (US) Air Force (USAF) 45th Space Wing, and Department of Commerce (DoC) National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Spaceflight Meteorology Group (SMG).

Manned flights launch and land at the Kennedy Space Center (KSC) adjacent to USAF Cape Canaveral Air Force Station (CCAFS) in Florida and also land at USAF Edwards Air Force Base (EAFB) in California. KSCWO provides daily staff meteorological support to KSC and the Space Shuttle and Constellation programs.

The ELV program operates from many locations, including CCAFS, USAF Vandenberg Air Force Base in California, NASA Wallops Flight Facility in Virginia, and the U.S. Army Ronald Reagan Ballistic Missile Defense Test Site on Kwajalein Island. KSCWO ensures that DoD weather support at DoD sites meets NASA requirements through training, technology, and tools.

KSCWO is the NASA lead for the joint NASA and USAF Lightning Advisory Panel (LAP), which provides independent scientific assessments of changes to the lightning launch commit criteria (LLCC) and technical guidance about lightning-related issues on facilities and ground operations. The U.S. Department of Transportation (DoT) Federal Aviation Administration (FAA) utilizes the same LLCC at commercial spaceports.

In FY 2008, the KSCWO:

- Supported four Space Shuttle missions: STS-120, STS-122, STS-123 and STS-124;
- Helped develop and deploy a new system to detect lightning at KSC Launch Complex-39;
- Supported the Constellation program through infrastructure and requirements concept studies of Ares 1 and Ares 1-X rockets and Orion Crew Exploration Vehicle (CEV);
- Prepared first draft of a weather operations plan for Constellation Ground Operations;
- Developed an analytical tool to provide the probability of exceeding operational peak wind thresholds of hurricanes and tropical storms at landfall.

In FY 2009, the KSCWO will:

- Support the Space Shuttle and ELV programs;
- Expand its support for the Constellation program through increased meteorological activities for the Ares 1-X test flight in 2009 and for planning Ares and Orion programs;
- Prepare and recommend LLCC revisions to the LAP to improve launch operation;
- Increase capability of the hurricane peak wind analysis tool.

<u>Applied Meteorology Unit</u>

The Applied Meteorology Unit (AMU) is a joint venture of KSCWO, USAF 45th Space Wing, and NOAA NWS. The AMU is co-located with the 45th Weather Squadron located at CCAFS. The AMU develops, evaluates, and transitions weather technology into operations.

In FY 2008, the AMU:

- Completed an objective cost-benefit analysis of the impact on forecast skill of local numerical weather prediction models through elimination of selected weather towers at CCAFS and one of the daily radiosonde soundings from CCAFS;
- Developed optimal scan strategies for the new 5-cm Doppler dual-polarization weather radar, which will be deployed for use at CCAFS in 2009;
- Updated its Anvil Forecast Tool for the SMG-operated Advanced Weather Interactive Processing System (AWIPS) to improve evaluation of the threat from natural and triggered lightning during a returning Space Shuttle in the presence of an anvil cloud;
- Created composite soundings to display in AWIPS so that they could be overlaid on current observed soundings allowing forecasters to compare the current state of the atmosphere with climatology;
- Developed a tool to help the 45th Space Wing forecast the average wind speed and the speed and timing of the daily peak wind from the surface to 300 feet at KSC and CCAFS for the cool season October – April and provide the probability of the expected peak wind speed equal to or greater than each of the wind warning thresholds;
- Supported launch operations for four Space Shuttle, three Atlas V, three Delta II and one Delta IV.

In 2009, the AMU will:

- Conduct cost-benefit analysis of automating the calculation of the Volume Averaged Height Integrated Radar Reflectivity (VAHIRR), which is used in LLCC;
- Complete statistical wind guidance tool for Space Shuttle landings at Edwards Air Force Base (EAFB), which displays monthly-mean wind speed and probabilities of exceeding peak wind thresholds at EAFB;
- Determine the skill of different high-resolution Weather Research and Forecasting numerical weather prediction model configurations in forecasting wind cycling at EAFB to help SMG forecasters support Space Shuttle landings at EAFB;
- Update the probabilities of lightning climatologies for nine airfields in the NWS Melbourne County Warning Area using individual lightning strike data to improve the accuracy of the climatologies to support Space Shuttle landings and daily ground operations;
- Configure the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to provide guidance to SMG and NWS Melbourne in the event of incidents involving the significant release of harmful chemicals, radiation, and smoke from fires;
- Support Space Shuttle landings with HYSPLIT to track cumulus cloud development and visibility from smoke;
- Migrate the capabilities of the AMU-developed Severe Weather Tool and 45th Space Wing-developed Weak Waterspout Checklist into the 45th Space Wing Meteorological Interactive Data Display System (MIDDS) to support warm season May – September daily and launch operations at KSC and CCAFS.

<u>Spaceflight Meteorology Group</u>

Spaceflight Meteorology Group (SMG) is located at NASA Johnson Space Center (JSC).

In FY 2008, the SMG:
- Supported four Space Shuttle missions: STS-120 (23 October – 7 November 2007), STS-122 (7 – 20 February 2008), STS-123 (11 - 26 March 2008) and STS-124 (31 May – 14 June 2008);
- Provided an average of 32 unscheduled in-person weather briefings per Space Shuttle flight, in addition to normal activities;
- Coordinated with NWS and the Spanish and French weather services for weather radar data support to improve SMG assessments of Space Shuttle transoceanic abort landing site weather at Istres Air Base in France and Zaragoza or Moron air bases in Spain;
- Supported the Constellation Program with weather requirements for landing and recovery of the new Orion spacecraft and its crew;
- Provided extensive meteorological support to JSC during Tropical Storm Edouard and Hurricanes Gustav and Ike, including continued support from SMG staff members' homes after JSC had been evacuated;
- Hosted the 7th NASA Weather Users Forum in June 2008;
- Collaborated with AMU on technology development;
- Upgraded AWIPS workstation;
- Supported several educational outreach events.

In FY 2009, the SMG will:
- Support Space Shuttle mission;
- Support Constellation program, including upper air wind forecasts for the Ares 1-X launch scheduled for late summer 2009;
- Host the Range Commanders Council meeting in May 2009;
- Enable final agreement with the French weather service for access to real-time radar, lightning, wind and other observations.

Marshall Space Flight Center

The Natural Environments Branch (NEB) develops and implements weather support requirements for the Space Shuttle and Constellation programs, including development and evaluation of launch constraints.

In FY 2008, the NEB:
- Supported four Space Shuttle missions: STS-120 (23 October – 7 November 2007), STS-122 (7 – 20 February 2008), STS-123 (11 - 26 March 2008) and STS-124 (31 May – 14 June 2008);
- Performed day-of-launch analyses of upper air winds for evaluation of vehicle ascent loads;
- Developed or improved wind climatological data sets for safety margin analyses and day-of-launch procedures relating to upper air wind requirements;
- Prepared Program Requirements Document for the Ares 1-X test flight in 2009.

In FY 2009, MSFC will:
- Support the Space Shuttle program;
- Develop weather support architecture for Constellation program.

The Earth Sciences Branch in FY 2008 developed scan strategies and operations concepts for the new Doppler, dual polarization 5-cm weather radar at CCAFS. This work will continue in FY 2009.

## RESEARCH

Earth Science Division

NASA's Science Mission Directorate Earth Science Division (ESD) conducts a program of breakthrough research to advance fundamental knowledge on the most important scientific questions on the global and regional integrated Earth system. ESD research encompasses the global atmosphere; the global oceans including sea ice; land surfaces including snow and ice; ecosystems; and interactions between the atmosphere, oceans, land, and ecosystems, including humans. ESD's vision is to understand the changing climate, including weather, and, in association with national and international partners, apply this understanding for the well-being of society.

In FY 2008, NASA operated fifteen on-orbit satellites: ACRIMSAT, Aqua, Aura, CALIPSO, CloudSat, EO, GRACE, ICESat, Jason, Landsat-7, OSTM, QuikSCAT, SORCE, Terra, and TRMM. Acronyms are defined in at the end of the section, which lists primary weather and climate themes of on-orbit missions. On 24 February 2009, NASA's Orbiting Carbon Observatory (OCO) satellite did not reach orbit when the launch vehicle malfunctioned. NASA has six missions in development for launch in FY 2010 and later (refer to listing at the end of the section).

For missions beyond those currently in formulation and development, the principal determinant of the priority of NASA's Earth Science satellite science missions is described in the National Research Council report, entitled "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond," which was released in 2007. Many Decadal Survey missions will contribute to weather and climate research, such as the 3-D Winds mission to measure the three-dimensional tropospheric wind vector profile to improve weather prediction capability. The Decadal Survey recommended six satellite missions to develop longer-term reliable weather forecasts.

NASA aircraft- and surface-based instruments are used to calibrate and enhance interpretation of high accuracy, climate quality, and stable satellite measurements. NASA supports state-of-the-art computing capability and capacity for extensive global integrated Earth system modeling. NASA, in recording approximately 4 terabytes of data every day, maintains the world's largest scientific data and information system for collecting, processing, archiving, and distributing Earth system data to worldwide users.

Weather and climate are part of a continuum spanning all time and space scales. A core objective of ESD is to improve severe weather forecast duration and climate projection through analyses of global observations from satellites, process studies combining orbital and suborbital measurements, and assimilation of satellite measurements into research and operational weather and climate models. NASA is working on climate change models with spatial and temporal resolutions to contain severe weather phenomena.

The NASA Tropical Rainfall Measuring Mission (TRMM) satellite directly measures rainfall with a Japanese Precipitation Radar (PR), an active microwave instrument and the only such instrument in space; and indirectly with the NASA TRMM Microwave Imager (TMI), a passive microwave instrument. The National Oceanic and Atmospheric Administration (NOAA) and the US Navy utilize TMI data in their weather forecasts. In addition to operational utility of TRMM data to improve weather forecasts, ongoing research studies illustrate the complexity of the dynamics and thermodynamics of rainfall because of the strong influence of aerosols. The lack of knowledge about the interaction of clouds and aerosols represent a large uncertainty in climate models. Two examples show this research finding.

Bell et al. (Journal of Geophysical Research, vol. 113, D02209, doi:10.1029/2007JD008623, 2008) used TRMM to show that rainfall over the southeast US was significantly higher during the middle of the week than on weekends. Afternoon storms intensified in the midweek. Apparently, air pollution, which is more extensive during the week than on weekends, suppresses cloud-drop coalescence and early rainout from clouds, allowing more cloud liquid water to be carried aloft to produce an overall increase in rainfall.

Berg et al. (Journal of Geophysical Research, vol. 113, D14S23, doi: 10.1029/2007/JD009649, 2008) showed that rainfall estimated from the PR, an active instrument, and TMI, a passive instrument, exhibited large differences off the coast of China and extending east across the North Pacific storm track. The area is rich in sulfate aerosols, which produce high liquid water content clouds with either no precipitation or light rain or drizzle with small drops that were not detected by the PR because of the PR's lack of sensitivity. Measurements from NASA's Cloudsat helped solve the mystery.

In-situ measurements at island and continental stations have demonstrated conclusively that rainfall has a diurnal-period oscillation, especially in the tropics where most rainfall occurs over the Earth. The geographical distribution of the time of day of maximum rainfall remained a mystery until sustained high accuracy well calibrated tropical rainfall data were acquired by satellite. Liu and Zipser (Geophysical Research Letters, vol. 35, L04819, doi:10.1029/2007GL032437, 2008) used TRMM measurements to describe diurnal-period oscillations of surface rainfall, vertical structure of precipitation, and deep intense convection reaching the top of the troposphere. This breakthrough study could be achieved only with the TRMM PR instrument and will guide the sampling strategy for the Global Precipitation Measurement (GPM) mission in development for launch in 2013.

Assimilation of satellite data in models is an important theme throughout ESD's programs. Investigations are primarily supported through annual solicitations of competitive peer-refereed proposals. Institutionally, ESD supports the NASA Global Modeling and Analysis Office (GMAO), located at NASA's Goddard Space Flight Center, and the interagency Joint Center for Satellite Data Assimilation (JCSDA), located at the National Oceanic and Atmospheric Administration (NOAA) World Weather Building. Several years ago, JCSDA demonstrated an increase in NOAA's National Centers for Environmental Prediction (NCEP) global weather forecast skill produced by the assimilation of measurements recorded by NASA's Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua satellite. In FY 2009, the JCSDA Management Oversight Board decided to adopt the overarching short-term goal to contribute to making the forecast skill of the operational numerical weather prediction systems of the JCSDA partners internationally competitive by assimilating the largest possible number of satellite observations in the most effective way.

NASA airborne campaigns improve understanding of atmospheric processes and provide calibration and validation instruments for NASA satellites. The series of CAMEX airborne campaigns (CAMEX-3, 1998; CAMEX-4, 2001; Tropical Cloud Systems and Processes (TCSP), 2005; NASA African Monsoon Multidisciplinary Analyses (NAMMA), 2006) provided a wealth of new research findings into the genesis, intensity change, and three-dimensional multi-scale structure of tropical cyclones in the Atlantic Ocean, Gulf of Mexico, and eastern Pacific Ocean. In addition, the CAMEX airborne campaigns were a test-bed for new remote sensing technologies for satellite and aircraft platforms, retrieval algorithms, and predictive models. The recent scientific focus on tropical storm intensity change is particularly timely with the recent strengthened cyclone intensity in the Atlantic Ocean storm activity and the continuing challenge of accurately forecasting tropical cyclone intensity. As part of the NASA annual omnibus solicitation, called Research Opportunities in Space and Earth Science (ROSES), in 2008 NASA selected a science team to use NASA satellite and field campaign data on problems related to the formation and intensification of hurricanes.

NASA is planning the Genesis and Rapid Intensification Processes (GRIP) airborne campaign for summer 2010 to better understand how tropical storms form and develop into major hurricanes. NASA plans to use the DC-8 aircraft and the Global Hawk Unmanned Airborne System (UAS) and is soliciting proposals through ROSES 2009 for instrument teams that can achieve the required measurements. GRIP deployment is planned in Miami, Florida, for the DC-8, and Edwards, California (or Wallops Island, Virginia), for the Global Hawk. The Global Hawk will fly in the upper troposphere and stratosphere, and, with 30-hour flight duration, can easily reach all regions of the Atlantic, Caribbean, and Gulf of Mexico. It is anticipated that the NOAA Hurricane Research Division will participate and deploy one or two low-altitude P3 turboprops and possibly a Gulfstream IV jet for the upper troposphere.

The global water cycle represents the transport and transformation of water within the Earth system, and, as such, distributes fresh water over the Earth's surface. The water cycle operates on a continuum of time and space scales and exchanges large amounts of energy as water undergoes phase changes and is moved from one part of the Earth system to another. Through latent heat release from condensation and sublimation, the water cycle is a major driving agent of global atmospheric circulation. Clouds play a critical role in modulating the flow of energy into and out of the Earth system, while at the same time modulating the continuous supply of solar energy that keeps the water cycle in motion. So while the water cycle delivers the hydrologic consequences of climate changes, the global water cycle is both a consequence of, and influence on, the global energy cycle. Weather and the global water and energy cycles are intimately entwined. Inherent to the topic of storm formation and intensification are questions related to the structure and evolution of clouds and precipitation and their links to the kinematic and thermodynamic characteristics of the initial disturbance, the more mature wind system, and the surrounding environment. Of particular relevance to NASA are remotely sensed estimates of wind, temperature, and water (in all of its phases) and their validation via direct measurements of their distributions.

Heliophysics Division

The Earth, our home planet, in embedded in the outer atmosphere of a magnetic variable star, our Sun. As a consequence the Earth, and the planets of the solar system, are constantly influenced by the magnetic evolution of the Sun that produces a dynamic environment.

The Heliophysics Division of the SMD is organized to discover and communicate new scientific knowledge concerning the magnetic variability of the Sun, the effect of this variability on the planets of the solar system including the Earth, and the dynamic structure of the particle and field configuration of interplanetary space. The three areas of concentration in the Heliophysics Division's research program are theory, data, and modeling.

To support the effort of collection of data that characterizes the heliophysical environment, the Division operates a fleet of 15 missions involving 26 spacecraft. The region of space characterized is huge, extending from the Sun itself to the outer edges of the solar system and the heliosphere. To extend the research effort, new missions are under development, including the first two missions of the NASA Living with a Star program, the Solar Dynamics Observatory (SDO) and the Radiation Belt Storm Probes (RBSP).

Currently three NASA research missions contribute data to the national space weather community. This is done by either direct broadcast from the satellite to a combination of NASA and non-NASA ground stations, or by near real-time level zero data processing from the satellite and rapid, periodic updates of NASA data bases that are accessible to the public or other governmental agencies via internet. The Advanced Composition Explorer (ACE) spacecraft, an Explorer program research activity in extended mission status, provides data on the condition of the solar wind outside of the Earth's magnetic field. The ongoing success of the use of ACE data concerning the characteristics of the solar wind flowing toward the Earth has made this research mission a vital resource for the nation. Other such missions are Solar and Heliophysics Observatory (SOHO), a joint program with the European Space Agency, and the Solar Terrestrial Relations Observatory (STEREO), a Solar Terrestrial Probes Program mission. The successful use of the direct broadcast modes of ACE and STEREO has lead to the inclusion of this type of mode into the RBSP project. SDO has a separate, high speed, data link that will make near real-time solar data from this mission available to interested users with a few minutes delay between collection and delivery to Internet customers.

NASA also supports the development of models and new theories both with the research and analysis program and the Targeted Research and Technology portion of the Living with a Star Program. As a quality assurance activity to validate the national research community model development, the agency operates the Combined Community Modeling Center, an interagency collaborative activity involving the NSF, NOAA, and DOD, which is located at the Goddard Space Flight Center. The output of standard and requested computations using community provided models is available in near real-time via the Internet. A yearly conference entitled R2O (Research to Operations) is held to ensure the effective utilization of the supported models within the broad range of national space weather activities.

Brief summary of the correlation of NASA operating satellite missions with OFCM themes. *Acronyms: ACE, Advanced Composition Explorer; ACRIMSAT, Activity Cavity Radiometer Irradiance Monitor SATellite; CALIPSO, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation; CloudSat, Cloud Satellite; EO, Earth Observer; GRACE, Gravity Recovery and Climate Experiment; ICESat, Ice, Cloud, and land Elevation Satellite; OSTM, Ocean Surface Topography Mission; QuikSCAT, Quick Scatterometer; SORCE, Solar Radiation and Climate Experiment; STEREO, Solar Terrestrial Relations Observatory; TRMM, Tropical Rainfall Measuring Mission.*

| Satellite | Launch Date | Themes |
|---|---|---|
| ACE | Aug 1997 | Solar wind composition |
| ACRIMSAT | Dec 1999 | Climate variability and change |

| | | |
|---|---|---|
| Aqua | May 2002 | Air quality; carbon cycle; climate variability and change; ecosystems; water cycle; weather |
| Aura | Jul 2004 | Air quality |
| CALIPSO | Apr 2006 | Atmospheric composition; water cycle |
| CloudSat | Apr 2006 | Climate variability and change; water cycle; weather |
| EO | Nov 2000 | Carbon cycle; ecosystems |
| GRACE | Mar 2002 | Climate variability and change; water cycle |
| ICESat | Jan 2003 | Climate variability and change; water cycle |
| Jason | Dec 2001 | Climate variability and change; water cycle |
| Landsat-7 | Apr 1999 | Carbon cycle; ecosystems |
| OSTM | Jun 2008 | Climate variability and change; water cycle |
| QuikSCAT | Jun 1999 | Climate variability and change; weather |
| SORCE | Jan 2003 | Climate variability and change |
| STEREO | Oct 2006 | Solar coronal mass ejections |
| Terra | Dec 1999 | Air quality; carbon cycle; climate variability and change; ecosystems; water cycle |
| TRMM | Nov 1997 | Climate variability and change; water cycle |

Brief summary of the correlation of NASA missions in development with OFCM themes.
*Acronyms: LRD is launch readiness date. Acronyms are: NPP, National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project; LDCM, Landsat Data Continuity Mission; RBSP; Radiation Belt Storm Probes; SDO, Solar Dynamics Observatory; SMAP, Soil Moisture Active and Passive; GPM, Global Precipitation Measurement.*

| **Satellite** | **Planned Launch** | **Theme** |
|---|---|---|
| SDO | Nov 2009 | Solar interior and atmospheric processes |
| Glory | Dec 2009 | Air quality |
| Aquarius | May 2010 | Climate variability and change; water cycle |
| NPP | Jan 2011 | Climate variability and change; ecosystems |
| LDCM | Dec 2012 | Carbon cycle; ecosystems |
| RBSP | May 2012 | Solar influence on Earth and near-Earth space |
| SMAP | Mar 2013 | Climate variability and change; water cycle; weather |
| GPM | Jul 2013 | Climate variability and change |

# 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 fundamental and applied research on weather phenomena that are either life threatening or economically disruptive. Focus areas include:

- Better understanding and forecasting of hurricane track and intensity;
- Better quantitative precipitation forecasting and estimation;
- Optimal use of observations in numerical models; and
- The societal/economic impacts of improved weather information.

The total research support for FY 2008 was approximately 14 million and this funding level is expected to remain at the same in FY 2009. It is anticipated that a major study focused on tornadic storms will begin in FY 2009.

NSF supports research under the National Space Weather Program (NSWP). 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. Examples of NSF support of space weather include conducting a highly successful competition for space weather research grants and providing support for the Center for Integrated Space Weather Modeling (CISM), a multi-institutional effort led by Boston University and dedicated to providing advance warning of potentially harmful space weather events. NSF NSWP support in FY 2008 is about $14 million and is expected to be about the same in FY 2009.

## GLOBAL CHANGE

Under the U.S. Climate Change Research Program, NSF supports research and related activities that advance fundamental understanding of dynamic, physical, geochemical, 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 facilitates data acquisition and data management activities necessary for basic research on global change, promotes the enhancement of modeling designed to improve representations of Earth system interactions, and develops advanced analytic methods to facilitate fundamental research. NSF also supports fundamental social and economic 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 2008 funding for this area of research was about $205 million; in FY 2009 the funding level is expected to be about $221 million and support is anticipated to remain at this level after FY 2009.

AIR QUALITY

NSF supported fundamental research in the area of air quality helps develop improved understanding of the sources, formation, atmospheric processing and fates of ambient air pollutants. Atmospheric oxidant species (and their precursors), sulfur dioxide, nitrogen oxides, carbon monoxide, fine particles (and their precursors), and acids are important atmospheric constituents that influence air quality, and in turn habitability, human health and climate. Field experiments, laboratory studies, instrument development, new methods of chemical analysis, and improved models of atmospheric chemical reaction mechanisms, 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.

NOTE: NSF budget data is not captured in Tables 2.1-2.5.

# 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 Offices of Nuclear Reactor Regulation and New Reactors conduct reviews of nuclear power plant siting, design, construction, and operation while the Offices of Nuclear Material Safety and Safeguards and Federal and State Materials and Environmental Management Programs conduct similar reviews of materials and waste facilities. These reviews include consideration of meteorological factors. The offices also conduct rulemaking to establish regulatory requirements.

The NRC Regional Offices assure that NRC licensees comply with the regulatory requirements. Together with the NRC Office of Nuclear Security and Incident Response, they also carry out NRC responses to nuclear facility emergencies. The NRC Office of Nuclear Security and Incident Response has been evaluating performance of large scale (greater than 1000 people) evacuations due to natural and man-made causes in the contiguous 48 states. This is documented in NUREG/CR-6864, "Identification and Analysis of Factors Affecting Emergency Evacuations". An additional study continues to analyze the large evacuations of 2005.

The Office of Nuclear Regulatory Research (RES) plans, recommends, and implements a program of nuclear regulatory research for nuclear power plants and other facilities regulated by the NRC. RES provides technical support, technical tools, and information to identify and resolve safety issues for current and new designs and technologies through testing, data development, analysis and national and international collaboration. 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.

At the present time, the NRC is a user of meteorological information rather than a performer of 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. Further, the NRC will use current meteorological information and climatological predictions of long-term (100 years) extreme meteorological events to evaluate new reactor designs and sites. 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, nonradioactive materials, and the effects of extreme meteorological events on the safe operation of nuclear facilities.

Figure 3-NRC-1. Diablo Canyon Nuclear Power Plant, California. (Pacific Gas & Electric photo)

# 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 OF THE OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY (OFCM)

The mission of the OFCM is to ensure the effective use of Federal meteorological resources by leading the systematic coordination of operational weather requirements, services, and supporting research, among the Federal agencies. The high level focus and output as a result of carrying out this mission includes needs and requirements; issues and problems; studies, reports, plans, and handbooks; and crosscut reviews, assessments, and analyses.

OFCM’s objectives in carrying out its mission 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.

As detailed in the report which follows, this has been an excellent year for OFCM in carrying out its interagency activities. The accomplishments of FY 2008 were substantial and meaningful for the nation, and the foundation has been laid for a similarly productive FY 2009.

## 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 priorities, requirements, and issues related to services, operations, and supporting research, and also resolves 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 Chairperson.

The 15 Federal agencies that engage in meteorological activities or have a need for meteorological services are represented on FCMSSR. The FCMSSR membership includes: the Departments of Agriculture, Commerce, Defense, Energy, Homeland Security, the Interior, State and Transportation, and the Environmental Protection Agency, National Aeronautics and Space Administration, National Science Foundation, National Transportation Safety Board, Nuclear Regulatory Commission, the Office of Science and Technology Policy and the Office of Management and Budget (OMB).

## HIGHLIGHTS FOR FISCAL YEAR 2008 AND PLANS FOR FISCAL YEAR 2009

### NATURAL DISASTER REDUCTION

#### INTERDEPARTMENTAL HURRICANE CONFERENCE

The OFCM annually hosts the Interdepartmental Hurricane Conference (IHC) 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. The OFCM hosted the 62nd IHC in Charleston, South Carolina, March 3-7, 2008. The theme of the conference was Tropical Cyclone Operations and Research: Priorities for the Future. With strong partnerships and alliances built over many years, the conference was attended by approximately 200 people for the ninth consecutive year, including representatives from nine Federal agencies: DOC/NOAA, DOD (Navy, Air Force, and Army Corps of Engineers), NASA, NSF, DHS/FEMA, DOT/FHWA, DOI/USGS, USDA and DOE. Ms. Mary Glackin, Deputy Under Secretary of Commerce for Oceans and Atmosphere, set the tone for the meeting during her Monday afternoon keynote address. She emphasized the importance of collaborative partnerships for the nation's hurricane forecast and warning program, especially in the areas of data collection, modeling, research activities, and transition of research results to operations. She highlighted the ultimate purpose in the partnerships is to further improve capabilities in forecasting track and intensity, storm surge, rainfall/flooding, storm structure, and sea state (waves)—all supported by improved observations from new and traditional sensors and sensor systems.

Objectives of the 2008 IHC included the following: (1) review the Nation's tropical cyclone forecast and warning program from end-to-end; (2) update the National Hurricane Operations Plan for 2008; (3) review the 2007 Joint Hurricane Testbed (JHT) projects, and identify candidates that may be successfully transitioned into operations; (4) examine how hazard risk reduction improvements can be made through stronger local partnerships and alliances; and (5) as recommended in the Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead, begin developing an interagency implementation strategy for the tropical cyclone research priorities.

It was clear from the first workshop, Interagency Priorities for Tropical Cyclone Research, that all agencies are doing important, relevant research against the research priorities outlined in Chapter 5 of the Strategic Research Plan. The partnerships required to tackle all the priorities are well accepted, with normal agency concerns remaining regarding control and funding. Some potential gaps and deficiencies were highlighted during the workshop: (1)

the United States is not producing enough new personnel with the education and training required for improving tropical cyclone forecasts via advanced data assimilation and numerical modeling systems; (2) there is slow progress on wind lidar (global 3D wind solution); (3) we need increased emphasis in the area of operationalizing data; (4) we need improved calibration, validation and quality control; (5) we need Observing System Simulation Experiments for impact definition; and (6) civil agencies lack targeted funding for transition of research to operations (such as DoD's 6.4 funding). The workshop, in conjunction with all of the other sessions conducted at the 62nd IHC, provided a baseline of research activities to track against the research priorities outlined in Table 5.1 of the Strategic Research Plan.

The workshop, Strong Local Partnerships: The Keys to Success, which related to Section 5.3 (Research Needs in the Social Sciences) in the Strategic Research Plan, provided some key take away points. All emergencies are local, with local emergency managers (EMs) charged to lead hazard preparation, response and recovery. In this regard, it's important that EMs: (1) convene pre-hurricane public talks designed to define actions; (2) prepare citizens to act in advance of hazards (e.g., develop Community Emergency Response Teams); and (3) sequester local elected leaders and ensure that they understand the plan of action. To be successfully prepared, local partnerships are vital (e.g., with local NWS WFO; local, state, regional and Federal officials; neighborhood associations; and media). Additionally, the workshop highlighted that current decision support systems (e.g., television overrides, Connect-CTY, WebEOC) and those in development—like the Integrated Public Alert and Warning System (IPAWS)—have the potential to further improve hazard preparation, response and recovery by enabling the dissemination of critical information to all citizens of communities, including citizens with language barriers, disabilities, economic constraints, and those with literacy challenges.

Actions resulting from the conference included: (1) Update and execute the National Hurricane Operations Plan for the 2008 hurricane season; (2) Analyze tropical cyclone research activities presented at the 62nd IHC and other subsequent forums with respect to the priorities established in Table 5.1 of the interagency strategic research plan; (3) Identify overlaps, gaps, areas for collaboration and leveraging opportunities; and (4) Establish the next steps needed to fill the gaps. The IHC was extremely successful in bringing the operational and research communities together to further improve the tropical cyclone forecast and warning program. It was also successful in addressing the needs of the Federal agencies and user communities that have a stake in the nation's tropical cyclone program. Finally, the conference provided a baseline of research activities that will enable the development of an interagency implementation strategy for the tropical cyclone research priorities, which can be reviewed at subsequent IHCs. The 2009 IHC is being planned for St. Petersburg, Florida.

## TROPICAL CYCLONE RESEARCH AND DEVELOPMENT PLAN

The tropical cyclone forecast and warning program is an interdepartmental collaboration to provide the United States and designated international recipients with forecasts, warnings, and assessments concerning tropical and subtropical weather systems. Previously mentioned in Section 3, the three centers that cooperate to provide the operational forecast and warning services are NWS's Tropical Prediction Center/National Hurricane Center (TPC/NHC), NWS's Central Pacific Hurricane Center (CPHC), and DoD's the Joint Typhoon Warning Center (JTWC). The Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead (Feb 07) provides a strategy for continuing to improve the effectiveness of operational forecasts and warnings through strategic coordination and increased collaboration among the major players in the operational and research and development (R&D) communities. The plan notes that vast improvements in tropical cyclone prediction are attainable with focused research efforts, enhanced transition of research to operations capabilities, strong interagency partnerships, coordination, and planning, and most importantly, sufficient resources—both human and infrastructure. This strategic plan has become the underpinning of NOAA's Hurricane Forecast Improvement Program and provides a foundation for Navy and NASA research as well as supporting NSF's related activities. In response to direction from the Interdepartmental

Committee for Meteorological Services and Supporting Research (ICMSSR), the OFCM formed the Working Group for Tropical Cyclone Research with cochairs from NOAA and the Navy. In FY 2009, the Working Group will be developing an implementation strategy for the research objectives outlined in the strategic research plan. The ultimate goal is to prevent loss of life and injuries and to reduce the nation's vulnerability to these potentially devastating storms.

POST-STORM DATA ACQUISITION

The OFCM continued to coordinate, as required, timely post-storm data acquisition surveys in response to Presidentially declared natural disasters and other agency requirements to evaluate, for example, the impact on coastal ecosystems. These natural disaster reduction efforts contribute to the determination of the intensity and magnitude of storms, and, in many cases, help to determine the extent of damage for use in Presidential disaster declarations. The additional data collected after hurricane landfall is also used in validating modeling efforts with both emergency management models (e.g., FEMA's HAZUS) and hurricane storm-surge models (e.g., NOAA's SLOSH). These models are used in real time to assist decisionmakers in evacuation decisions and procedures. Post-storm data are also used to update FEMA Flood Insurance Rate Maps. Under the 5-year Umbrella Agreement and an FY 2008 funding agreement between OFCM and the U.S. Air Force for up to $22,000 in reimbursable support, the Civil Air Patrol flew 17 missions in support of tornado and hurricane damage assessments, flood assessment, survey of potential dam breaks, glacial lake damming in Alaska, and a pre-storm hydrology survey in Hawaii. This support will continue in FY 2009 at a planned level of $25,000 set aside for these missions.

URBAN METEOROLOGY

NATIONAL WILDLAND FIRE WEATHER NEEDS ASSESSMENT

An important contribution to urban meteorology is the National Wildland Fire Weather Needs Assessment which is being conducted by OFCM in concert with the agencies and stakeholders. Wildland fires from 2004 to 2007 set records for acreage burned and the number of fires have trended upwards more than 100 percent since the mid-1980s. Fire at the Wildland Urban Interface is a serious problem, with increasing intrusion into the urban landscape and loss of homes and other structures. In June 2005, the Western Governors' Association (WGA) urged NOAA to have the OFCM complete a national assessment of Federal, state, and local fire managers' needs for weather information in their wildfire and prescribed fire decisionmaking processes and develop a framework to meet those needs. The needs assessment has been completed, capabilities information has been gathered, and an initial gap analysis has been completed. The needs assessment identified 47 specific needs in nine functional areas and the initial gap analysis indicates just two of these needs may have no activity against them but, conversely, none of the needs may be considered fully met at this time. The OFCM briefed the results of the needs assessment and provided a copy of the summary report to the NOAA Science Advisory Board's Working Group on Fire Weather Research as part of their kickoff activities in October 2007. The results of the NOAA SAB's working group study have been incorporated into the draft final report. The OFCM also briefed the needs assessment results to the Committee for Climate Analysis, Monitoring and Services in the fall of 2007. For FY 2009, the OFCM will form the Working Group for Wildland Fire Weather to complete the final report which will outline the needs, capabilities, gaps, and a framework to address the needs, to be completed in the spring of 2009.

ATMOSPHERIC TRANSPORT AND DIFFUSION RESEARCH AND DEVELOPMENT

The OFCM developed an atmospheric transport and diffusion (ATD) implementation strategy for the recommendations for which OFCM has primary responsibility in the Federal Research Needs and Priorities for Atmospheric Transport and Diffusion Modeling (September 2004) report. The implementation strategy has three parts: (1) working with the agencies to identify and improve a baseline set of national ATD modeling capabilities; (2) helping the agencies implement a common framework for model development and evaluation; and (3) recommending criteria for multifunctional joint urban test beds ["urban" describes a metropolitan area and its interfaces with surrounding areas]. In accordance with this, OFCM formed a Joint Action Group for Joint Urban Test Beds (JAG/JUTB) under the Working Group for Urban Meteorology (WG/UM); and this joint action group has met frequently, and is continuing work to develop an operational concept document for multifunctional joint urban test beds to provide services and data to model developers, test and evaluation personnel, and users. The operational concept document will include capabilities and benefits, management structure, infrastructure requirements, selection process, implementation framework, definitions, and characteristics of urban scales. The joint urban test beds will support the following functional areas: severe weather (e.g., hurricanes, tornadoes, heat waves and cold spells, drought, and wildland fires), homeland security (dispersion of hazardous materials), climate, air quality (e.g., particulate matter aerosols), and water quality (e.g., deposition of airborne contaminants on water sources and waterborne transport of contaminants). JAG/JUTB is currently planning to pursue implementation of a JUTB over the National Capital Region first; this JUTB would be the proof of concept and our experience with it would allow for the improved development of an operational concept document.

GEORGE MASON UNIVERSITY ATMOSPHERIC TRANSPORT AND DISPERSION MODELING CONFERENCE

George Mason University (GMU), Fairfax, Virginia, conducted its 12th Annual Conference on Atmospheric Transport and Dispersion Modeling in July, 2008. The OFCM cosponsored the event, together with the Joint Science and Technology Office for Chemical and Biological Defense, Defense Threat Reduction Agency (DTRA); the Naval Surface Warfare Center, Dahlgren Division (NSW-CDD); and GMU. Themes for the conference were: improve understanding of atmospheric transport and diffusion processes; support homeland security requirements; and share experience across different sectors. Participants included representatives from DOD, EPA, DOE, NOAA, universities, private companies and other agencies doing related research, as well as scientists from other countries. Technical topics of interest for the conference were: new developments in basic theories of boundary layer models and transport and diffusion models; urban-scale meteorological and dispersion experiments and models; computational fluid dynamics (CFD) model theory and applications; field experiments and laboratory experiments concerned with boundary layer studies and turbulence and dispersion studies; mesoscale meteorological modeling for input to transport and dispersion models; the use of remote sensing technology in boundary layer and transport and dispersion studies; model evaluation methods, uncertainty/sensitivity analyses, and risk assessments; improvements in model inputs (e.g., land-use data, 3-D building data) and output visualizations; and methods and criteria for emergency response and decision making. The OFCM conducted a special session related to the OFCM's ongoing work with other members of the Federal meteorological community to implement the recommendations in the report, Federal Research Needs and Priorities for Atmospheric Transport and Diffusion Modeling. The special session provided much information on benefits of joint urban test beds; it was chaired by Dr. Walter Bach, Jr., Program Manager of the Environmental Sciences Division of the U.S. Army Research Office.

CLIMATE

The OFCM supports the U.S. Climate Change Science Program (CCSP) and participated in extensive reviews of the Synthesis and Assessment Products produced in FY 2008, offering substantive comments accepted into the transportation product, in particular. The Federal Coordinator, through his participation on the Committee on Environment and Natural Resources (CENR), will continue to review and provide concurrence on CCSP Synthesis and Assessment Products.

OPERATIONAL PROCESSING

OFCM's activities regarding Operational Processing Centers (OPC) continue to improve processing and backup capabilities of NOAA's National Centers for Environmental Prediction and Office of Satellite Data Processing and Distribution, the Air Force Weather Agency, and the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center and Naval Oceanographic Office. During FY 2008 in response to a request from the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Senior Users Advisory Group (SUAG), COPC fostered the synergistic coordination, program development, and implementation of NPOESS data exploitation strategies. Also in FY 2008, the agencies signed the Data Acquisition, Processing, and Exchange (DAPE) Memorandum of Agreement to update and formalize these activities among the operational processing centers. The Environmental Satellite Data Acquisition (ESDA) annex to the DAPE MOA is in final coordination and will be completed in FY 2009. This annex will replace the expiring Shared Processing Program (SPP) agreement which provides for funding to support the exchange of extensive volumes of data.

ANNUAL FEDERAL PLAN

In October 2007, the OFCM issued The Federal Plan for Meteorological Services and Supporting Research–Fiscal Year 2008. 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 overlap and duplication among the agencies. It is a comprehensive publication that documents proposed programs for FY 2008, and reviews agency programs for FY 2007. The feature article for the FY 2008 Annual Federal Plan describes a crosscutting assessment of Federal agency hydrometeorological products, services, and supporting research. The feature article for the FY 2009 Annual Federal Plan focuses on natural disasters in the urban environment.

WEATHER INFORMATION FOR SURFACE TRANSPORTATION

Since 1998, OFCM has made weather services and research and development (R&D) activities supporting the surface transportation community a priority for the Federal meteorological community. In June 2008, the Federal Coordinator for Meteorology provided a keynote address at the Fourth National Symposium on Surface Transportation Weather in Indianapolis, Indiana. As this area of weather products, services, and supporting research continues to grow, the expansion across international borders continues as well. At the invitation of the U.S. Embassy in Austria, the Federal Coordinator for Meteorology provided a keynote address at the Safety in Mobility conference held in Velden, Austria, in July 2008. The conference brought together experts and stakeholders from across the European continent to discuss issues and move forward in this important area. In addition, the Federal Coordinator made a presentation at the Intelligent Transportation Systems World Congress held in New York City from 16-20 November 2008. The OFCM will continue to work with the agencies to advance weather information for surface transportation throughout FY 2009, focusing on areas such as: current and emerging capabilities; transition of research to operations to improve products and services; getting the right message out and the need for social science involvement; education and outreach; the need for metrics to measure success and guide resource allocation; identifying gaps and setting research priorities; and exploiting the opportunity for a near-term intermodal initiative to develop and demonstrate emerging capabilities.

AVIATION WEATHER

The OFCM continued to participate in the Next Generation Air Transportation System (NextGen) Weather Working Group Executive Committee and the Friends/Partners in Aviation Weather (FPAW). We attended the FPAW meeting at the National Business Aviation Association annual gathering in Orlando, Florida, in October, 2008, and presented results of the 10-year effort to reduce weather-related aviation accidents. The OFCM completed the analysis of National Transportation Safety Board accident information now finalized through 2006 to assess performance toward the goal of reducing weather-related fatal aviation accidents by 80 percent over the 10-year period from 1997 through 2006. Although the National Aviation Weather Program achieved significant progress over this period, particularly in the area of general aviation, the second five years of the 10-year period showed a marked slow down in the decline of accident rates and the ambitious 80 percent reduction goal was not achieved. The analysis of the accident data raised a number of questions and the cause of the slow down is not readily apparent. It is likely a combination of a number of factors and the OFCM will be working with the NTSB and others in FY 2009 to develop an understanding of the change in the trend lines, how the program can sustain the progress which has already been made, and how to jump start additional progress toward the overall 80 percent reduction. The final report assessing this goal will be published in FY 2009. The OFCM continues to implement the National Aviation Weather Program, and is working with the agencies to advance meteorological standards, improve products, enhance services, and participate in research that contributes to the overall goal of providing the best state-of-the-art information to aviation end users where and when they need it. The OFCM has monitored the development of the Next Generation Air Transportation System concept of operations and functional requirements for the network-enabled weather capability envisioned for NextGen, with special emphasis on complementary development of a broader environmental data cloud. OFCM's coordinating infrastructure will continue to contribute the collaboration in the aviation community.

SPACE WEATHER

The Committee for Space Weather continued to move forward to address the recommendations of the 2006 independent assessment of the National Space Weather Program (NSWP), including development of a new strategic plan for the NSWP. The new NSWP Strategic Plan is in final clearance within the Executive Office of the President, and OFCM expects to publish it in FY 2010, with a follow-on effort to craft an updated NSWP Implementation Plan. In a complementary effort, the Committee prepared and submitted a Space Weather Implementation Plan (SWxIP) as requested by the Committee on Environment and Natural Resources (CENR) Subcommittee for Disaster Reduction (SDR). Space weather was identified as one of the SDR's Grand Challenges for Disaster Reduction and SDR requested that the OFCM spearhead an effort, through the NSWP, to develop the SWxIP. Another significant NSWP effort in FY 2008 was the completion of the report Impacts of NPOESS Nunn-McCurdy Certification and Potential Loss of ACE Spacecraft Solar Wind Data on National Space Environmental Monitoring Capabilities, documenting the results of a study requested by the Office of Science and Technology Policy (OSTP). The report was submitted to OSTP in January 2008 following high-level coordination in each of the stakeholding agencies, and the interagency study team briefed the results to staff from both OSTP and OMB in February. The report identifies a number of significant impacts resulting from the expected loss of space environmental sensing capability and the report is marked For Official Use Only. The OFCM received a follow-on request from OSTP to conduct a mitigation study in FY 2009.

PHASED ARRAY RADAR

The Working Group for Multifunction Phased Array Radar (WG/MPAR), cochaired by NOAA/OAR, FAA, DHS, and DOD/Air Force, continued to move forward with a coordinated approach to risk reduction for applying phased array radar to concurrent air and weather surveillance. The OFCM, in conjunction with OSTP's Committee on Environment and Natural Resources, Subcommittee on Disaster Reduction (SDR), hosted a symposium on MPAR in Norman, OK, in October 2007 with the theme Leveraging Technology to Build a Next Generation National Radar System. More than 180 people attended the symposium, representing Federal agencies, academia, military laboratories, and the radar industry. The fundamental message/outcome from the symposium was that now is the time to begin the evaluation of MPAR, and a risk-reduction implementation strategy was needed.

Items driving the urgency to begin the evaluation of MPAR are: (1) legacy weather and aircraft surveillance radars are nearing the end of their lifecycles; (2) society demands greater protection of life and property, more timely warnings of hazardous weather events, and increased accuracy, spatial resolution and lead times for severe weather warnings; (3) the need for enhanced capability to track non-cooperative aircraft and other airborne threats to safety and security is paramount; (4) the multifunction capability of MPAR leads to reduced lifecycle costs; and (5) a risk-reduction implementation strategy will reduce uncertainties and produce cost-effective alternatives, which will lead to a sound business case. The WG/MPAR developed a coordinated implementation strategy in early 2008, which formed the anchor point for ongoing planning and coordinated action across NOAA, DOD, DHS, and the FAA. In late FY 2008, the OFCM and WG/MPAR completed a service improvement assessment for weather surveillance which mapped the linkages from basic capabilities expected of a PAR system, to derived capabilities, and subsequently to anticipated service improvements. A similar analysis is underway for air surveillance and should be completed in FY 2009. Several WG/MPAR members also participated in the Interagency Surveillance Summit in June 2008 and the Federal Coordinator for Meteorology is expected to participate in the summit to be held in December 2008.

Also in late FY 2008, the National Academies' Board on Atmospheric Science and Climate (BASC) Committee on the Evaluation of the MPAR Planning Process delivered their report. Their overarching recommendation was to continue the MPAR research and development, and they noted the need to develop a detailed set of requirements and that the cost estimates were "promising, but embryonic." The WG/MPAR is working on defining requirements and drafting an operations concept for MPAR. The committee's principal findings were: (1) phased array technology can offer some significant technical advantages; (2) significant technical questions for weather surveillance need to be answered (i.e., dual polarization); (3) implementation of a network of about 350 MPAR systems could replace existing NWS and FAA radars; (4) replacement of existing systems alone cannot meet all agency mission requirements with the main issue of low-level coverage of weather and non-cooperative aircraft; and (5) cost-benefit considerations are embryonic at this time and a series of trade studies are needed.

Over the last year, DHS supported targeted research using the National Weather Radar Testbed at the National Severe Storms Laboratory in Norman, OK, and additional future funds were programmed for phased array radar work in NOAA. At its meeting on September 29, 2008, the ICMSSR supported the creation of a senior policy council for MPAR within the Federal meteorological coordinating infrastructure. This council would begin addressing policy issues among the key stakeholding agencies as anticipated funding increases materialize in the years ahead. Finally, the WG/MPAR will be planning for a second MPAR Symposium expected to held in early FY 2010.

## CROSSCUTTING HYDROMETEOROLOGICAL ASSESSMENT

The OFCM hosted a one-day hydrometeorology mini-workshop in September 2008 to bring together the relevant Federal agencies to initiate discussion in the following areas: (1) programs and initiatives in the agencies; (2) product suites and services, both current and experimental; (3) needs and requirements; (4) potential benefits from improved products and services; (5) challenges and gaps in products and services; (6) research underway, opportunities, and plans to meet identified gaps; (7) processes for transitioning research into operational applications; and (8) related education and outreach activities. The workshop spurred interest among the participants to see what others are working on and to continue gathering needs and requirements and identifying priorities and gaps. Although lacking some details at this stage, the participants were appreciative of this first step to bring the community together to begin addressing these issues. Attendees identified additional future participants and the OFCM will conduct a follow-on mini-workshop on hydrometeorological products, services, and supporting research in December 2008.

## CRITICAL SKILL SHORTAGES

In 2007, the Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead, identified an important example of a deficiency in workforce development when it noted the insufficient production of new personnel with the education and training required for improving tropical cyclone forecasts via advanced data assimilation and numerical modeling systems. The Data Assimilation Education Forum at the 88th Annual Meeting of the American Meteorological Society in January 2008, co-sponsored by the OFCM, corroborated this shortage and revealed the lack of personnel with programming and computational skills for high-end computers. Anecdotal evidence indicates additional potential shortages in the areas of probability, radar meteorology, and tropical meteorology. At its meeting on September 29, 2008, the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) agreed to establish the Joint Action Group for Critical Skill Shortages to identify other critical areas, collect information, and conduct an analysis of the Federal sector's current and projected critical skill shortages. The group will then make recommendations to address the skill shortages identified. An interim report is expected in late FY 2009 and a final report in FY 2010.

### ENVIRONMENTAL LITERACY

The OFCM has laid out a vision, framework, and methodology which the office will embrace to systematically promote environmental literacy through interdepartmental collaboration within the OFCM coordinating infrastructure. The methodology defines how to determine if an opportunity to promote environmental literacy exists. It also describes the method to be used to determine the target public, private, and/or academic sector audiences and how to reach them. Determining the target audiences' needs and a means for assessing how those needs are being met is incorporated into the methodology as well. Executing this methodology will result in a nation better able to understand the linkages between weather and climate and personal and professional choices and build a national capacity to solve problems and respond to change. It will provide for a more environmentally literate citizenry. In this regard, the OFCM developed an implementing strategy/action plan to make environmental literacy a crosscutting priority within the OFCM coordinating infrastructure. The OFCM is also continuing its support of an American Meteorological Society undergraduate scholarship in the atmospheric and related oceanic and hydrologic sciences.

### GUIDANCE AND PRACTICES FOR XML

In 2007, the charter for the Committee for Environmental Information Systems and Communications (CEISC) Joint Action Group for Extensible Markup Language and Web Services (JAG/XML-WS) was enhanced so that this group would serve as the primary national collaboration forum to work on three primary objectives. The objectives are: (1) Establish agreed national standards (develop by JAG/XMLWS or obtained from national or international standards bodies) and common services and components for common weather information exchange in a net-centric operations environment; (2) Serve as the national working body to develop the U.S. position and candidate standards for adoption consideration for the newly formed World Meteorological Organization (WMO) Expert Team on the Assessment of Data Representation Systems; and (3) Support the development of a specialty subset of national standards specifically related to aviation weather. This is needed both in support of the Next Generation Air Transportation System (NextGen) and to support the Federal Aviation Administration (FAA) engagement with EUROCONTROL on a similar need for equivalent aviation system modernization. The desired intent is to develop common standards to be used both by EUROCONTROL and by NextGen. The group developed the U.S. position and supported both WMO and ICAO meeting in FY 2008 and the ultimate outcome remains in development.

### COLLABORATION WITH NAS/NRC BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE

The OFCM continued its mutually beneficial interactions with the National Academies National Research Council (NRC). The Federal Coordinator for Meteorology continued to participate in NRC Board on Atmospheric Sciences and Climate (BASC) strategic planning workshops and regularly scheduled meetings and is expected to continue participation throughout FY 2009. In FY 2008, BASC's Committee on the Evaluation of the Multifunction Phased Array Radar Planning Process completed its study, originally performed at the request of the OFCM.

### COLLABORATION WITH THE COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

### CENR PRINCIPALS

The Federal Coordinator continued to be a participant on the CENR, and continued to assist CENR through review and concurrence of CENR reports and materials. This activity will continue in FY 2009.

### SUBCOMMITTEE ON DISASTER REDUCTION

The OFCM has been an active participant in the work of the CENR Subcommittee on Disaster Reduction (SDR). SDR has developed Grand Challenges implementation plans to improve the nation's capacity to prevent and recover from disasters. The implementation plans include such topics as assessing disaster resilience, understanding the natural processes that produce hazards, and promoting risk-wise behavior. As mentioned earlier, space weather was identified as one of the SDR's Grand Challenges for Disaster Reduction. OFCM is committed to working with SDR to provide a forum for information sharing, development of collaborative opportunities, and interactive dialogue with the U.S. policy community to advance informed strategies for managing risks associated with natural and technological disasters.

AMERICAN METEOROLOGICAL SOCIETY

The OFCM supports AMS endeavors by participating in AMS conferences and workshops and other environmental science education and outreach programs, including for example the January 2008, 88th AMS Annual Meeting in New Orleans, Louisiana. As part of the annual meeting, OFCM cosponsored the Forum on Education in Data Assimilation. The Federal Coordinator continues to serve as a member of the AMS Commission on the Weather and Climate Enterprise (CWCE).

INTERNATIONAL COLLABORATION

At the invitation of the U.S. Embassy in Austria, the Federal Coordinator for Meteorology provided a keynote address on Weather Information for Surface Transportation (WIST) at the European conference on Safety in Mobility, held in Velden, Austria, in July 2008. In addition, the Federal Coordinator made a presentation at the Intelligent Transportation Systems World Congress held in New York City from 16-20 November 2008.

PUBLICATIONS

The following publications were prepared in hard copy and/or have been placed on OFCM's Web site (www.ofcm.gov) during FY 2008:

- The Federal Plan for Meteorological Services and Supporting Research-Fiscal Year 2008
- National Hurricane Operations Plan
- Impacts of NPOESS Nunn-McCurdy Certification and Potential Loss of ACE Spacecraft Solar Wind Data on National Space Environmental Monitoring Capabilities (For Official Use Only)
- Federal Meteorological Handbook No. 11 - Doppler Radar Meteorological Observations (WSR-88D) Part A - System Concepts, Responsibilities, and Procedures
- MPAR Service Improvement Assessment
- DRAFT -- National Post-Storm Data Acquisition Plan
- DRAFT -- National Severe Local Storms Operations Plan
- DRAFT -- Federal Lightning Capability Requirements

Please see www.ofcm.gov for a complete listing of all available OFCM publications.

# APPENDIX B

# WORLD WEATHER WATCH 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 Watch (WWW) program. Until 1983, DOC published a separate report on WWW plans. Beginning with the 1983 edition of the Federal Plan for Meteorological Services and Supporting Research, a section on the WWW 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 WWW.

## BACKGROUND

The World Meteorological Organization (WMO), with 182 member states and 6 member territories, is an intergovernmental organization affiliated with the UN to facilitate international cooperation in the fields of meteorology, climate, and operational hydrology. The United States became a Member of the WMO in 1951. The purpose of the WMO is to coordinate the collection and distribution of meteorological data for weather forecasts for national interests as well as global aviation and maritime activities.

Development of the technology and the systems to obtain meteorological observations, especially over the oceans, presents formidable problems. The collective use of satellites, aircraft, ships, radar, anchored and drifting buoys, and balloons can help provide comprehensive data about the atmosphere over the entire globe. However, this system is too complex and expensive 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 through WMO's predecessor, the International Meteorological Organization.

This continuing need to advance the science of meteorology through international cooperation prompted the President of the United States in 1961 to propose to the United Nations (UN) the establishment of an international effort in weather prediction. The UN responded by calling upon the 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 atmosphere dynamics that govern weather. The WMO responded to the UN request in 1963 with the concept of the World Weather Watch (WWW) and a Global Atmosphere Research Program (GARP). The WWW is an operational system to coordinate the rapid collection and exchange of weather data among all WMO Members as well as for the dissemination of weather forecast products from centralized processing centers.

## GOALS AND ORGANIZATION

On January 1, 2008 the World Meteorological Organization (WMO) Secretariat located in Geneva, Switzerland, reorganized. The reorganization was in response to the fifteenth WMO Congress (May 2007) approval for a new framework for the Results-based Management of the Organization. The Secretariat is now divided into departments aligned according to strategic themes. The WWW Program is located in two departments. The Observing and Information Systems Department (OBS) is responsible for managing the WWW Global Observing (GOS) Program, the WWW Global Telecommunication System (GTS), the WWW Data Management (WDM), the WWW System Support Activity, and the WWW Instruments and Methods of Observations (IMOP). The Weather and Disaster Risk Reduction Services Department includes the Global Data Processing and Forecasting System (GDPFS) Program and Emergency Response Activities.

The WWW is the World Meteorological Organization's (WMO) core activity and backbone to coordinate a global observing network and movement of observations around the world in real time through the GTS. The OBS with its WWW elements supports WMO top-level objectives; 1) to produce more accurate, timely and reliable forecasts and warnings of weather, climate, water and related environmental elements; and, 2) to improve the delivery of weather, climate, water, and related environmental information and services to services to the public, governments and other users.

## INTEGRATED GLOBAL OBSERVATIONS

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 to a certain extent 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.

The WMO is working through its Members to improve elements of the WWW such as the Global Climate Observing System (GCOS), the Regional Basic Synoptic Network (RBSN) and environmental meteorological satellite coverage. However, most data collection platforms represent stand-alone systems and do not benefit from the synergistic effects of integration. Under WMO's OBS Department the WWW GOS will evolve to a WMO Integrated Global Observing System (WIGOS) which will integrate various meteorological observing systems. The components of WIGOS (surface and space-based) include: weather observing networks traditionally part of GOS, atmosphere composition networks including the Global Atmosphere Watch (GAW), marine meteorological networks and arrays including buoys and voluntary observing ships, hydrological observing networks, and the climate components of various atmospheric, oceanographic and terrestrial observing systems contributing to GCOS.

As part of the WIGOS evolution the OBS Department is developing the WMO Information System (WIS) which will modernize the GTS through new communication technology and concepts. WIS is the pillar of WMO strategy for managing and moving weather, water and climate information in the 21st century. WIS provides an integrated approach for routine collection and automated dissemination of observed data and products as well as data discovery, access and retrieval services for all weather, climate, water and related data produced by Members. It is being built on the GTS and the WWW. WIS will encompass three types of centers: Global Information System Centers (GISC) for collection and distribution of routine data; Data Collection or Production Centers (DCPC) for generation of sets of data, forecast products, processed or value-added information and archives; and National Centers.

The responsibilities of U.S. Federal agencies in the WWW 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. The United States is one of three (Russia and Australia are the other two) World Meteorological Centers, which include World Data Centers and the principal telecommunication gateway for the WMO's Global Telecommunication System (GTS).
- Department of State (DOS). The DOS Bureau for International Organizations is the principal source for U.S.-appropriated funds to the WMO. The DOS maintains relations with developing nations and, through NOAA and the WMO, assists developing nations through the Voluntary Cooperation Program (VCP) to improve their national weather services. DOS also develops appropriate multilateral and bilateral arrangements to further international participation.
- National Science Foundation (NSF). The NSF stimulates and supports basic and applied research by scientists primarily in academia on atmospheric and ocean circulation and models. 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 the DOD's operations is global. As such, the observation, telecommunications, and data-processing programs of the DOD 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. DOD also

operates a polar-orbiting meteorological satellite program.

- Department of Transportation (DOT). DOT's Federal Aviation Administration's terminal aerodrome meteorological observations and air traffic telecommunication network provides an important source of data to the WWW.
- Department of Homeland Security (DHS). Through the U.S. Coast Guard, DHS provides personnel to support NOAA's National Data Buoy Center (NDBC) in developing, deploying, operating, and evaluating data buoy systems.
- National Aeronautics and Space Administration (NASA). NASA performs research, develops aerospace technology required for an effective global weather system, and provides data from R&D satellites to the WWW. NASA launches for NOAA both polar- orbiting and geostationary satellites.
- Department of the Interior (DOI). DOI's U.S. Geological Survey (USGS) is an important source of hydrologic data used in flood forecasting. The USGS, in addition to its advisory role on water issues in the WMO, will assume a greater functional role in the WMO's emerging water program.
- Department of Agriculture (USDA). USDA is a valuable resource for surface climatological meteorological data from cooperating observers. The department's World Climate Observing Board is responsible for monitoring the impact of climate and extreme weather on both national and international commercial crops. USDA is on the WMO technical commission that works on agrometeorological issues

## THE WORLD WEATHER WATCH (WWW)

The WWW is an integrated member-operated observing system linked by the GTS and it 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 the Global Observing System (GOS). These elements are coordinated and closely integrated through three WWW support functions:

- The data management function coordinates, monitors, and manages the flow of data and products within the WWW system to assure their quality and timely delivery. It also includes the definition and use of code forms for data exchange.
- The systems support activity provides guidance, technical and scientific information, and training to those involved in the planning, development, and operation of WWW components.
- The implementation and coordination function assures the timely completion of the WWW implementation and effective support and maintenance of the WWW system.

### Global Observing System (GOS)

The GOS is a coordinated observing system, employing standardized techniques for making meteorological and marine surface observations on a worldwide scale. It is a composite system, containing surface-based (national networks), airborne (civil aviation), and space-based (satellite) subsystems. The main elements of the network and airborne subsystems include:

- The Regional Basic Synoptic Network (RBSN), staffed and automated, for both surface and upper-air observations.
- Fixed observing stations at sea, composed of 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.

### Airborne Observations

The WWW has pursued a class of automated airborne reporting systems such as the Automated Meteorological Data and Reporting (AMDAR) systems. Over 3000 aircraft now provide reports of pressure, winds, and temperature during flight. The amount of data from aircraft has increased dramatically during recent years -- from 78,000 reports in 2000 to over 200,000 reports in 2007. These systems are making a major contribution to the upper-air component of the GOS in regions where there is little or no radiosonde data.

The U.S. AMDAR program began in the early 1980's as a cooperative effort among ARINC (Aeronautical Radio, Inc.), the NWS, and the FAA. Over 150,000 reports of wind and temperature are sent every day in the Binary Universal Form for Representation of Meteorological Data (BUFR) code. These reports are provided by seven airlines: American, Delta, Federal Express (FedEx), Northwest, Southwest, United, and United Parcel Service (UPS). Global cooperation on AMDAR is facilitated by the WMO AMDAR Panel established in 1998 by a number of WMO members operating or intending to operate AMDAR programs. Australia, Canada, China, EUMETNET/E-AMDAR, Japan, New Zealand, Republic of Korea, Russia, Saudi Arabia, South Africa, and the United States have AMDAR programs. A number of new countries have directly indicated interest in the past year in developing AMDAR including Slovenia, the Czech Republic, Malaysia, Kenya, and Mauritius, who have also appointed focal points, and Singapore has recommenced exploring possibilities of using targeted data. Specific information and guidance has been provided to all countries. Additionally, Bulgaria and Croatia have begun exploring the potential of using AMDAR in their own national programs.

In addition to wind and temperature data collection, the U.S. program is expanding the operational parameters collected to also include water vapor and turbulence. Water vapor observations from over 75 aircraft, from two different sensors have been routinely available for assessment since early 2005. 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 algorithm is currently installed on 400 United Airlines aircraft, is available through the AirDat TAMDAR sensor, and will be added to several additional Southwest Airlines aircraft in the next year as well. EDR reports are being experimentally ingested into the FAA Graphic Turbulence Guidance (GTG) and as an initialization parameter.

Surface-based Observations

GOS employs both marine and land surface-based observing systems. Approximately 11,000 stations on land take observations at least once every three hours and often hourly of thermodynamic and wind-field parameters of the atmosphere. About 4,000 of the world's surface stations comprise the RBSN. Data from these stations are exchanged globally in real time. A subset of these surface stations are used in the Global Climate Observing System (GCOS) Surface Network (GSN). The United States operates 87 surface stations as part of the GCOS network. Many countries, including the United States, have available additional surface data from specialized mesoscale networks, such as Oklahoma's Mesonet, used for research, water management, and transportation needs. The United States operates about 73 surface stations on the Antarctic continent. Twenty are U.S. government sponsored of which only 4 report regular observations. The other 53 sites are sponsored through university programs.

The lower atmosphere is vertically profiled using a land-based global array of about 900 upper-air stations which deploy at least once per day a balloon-borne radiosonde capable of providing in-situ measurements of basic state parameters. Approximately 15 specially outfitted commercial ships provide upper-air observations over sparsely instrumented oceanic regions. The NWS operates 92 upper-air stations and supports 15 additional sites in the Caribbean and Pacific. For all U.S. activities (including DOD and other agencies), we have reported to WMO a total of 132 sites. The United States has also 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.

Marine Observations

Over the oceanic regions, the global observing system relies on ships, moored and drifting buoys, profiling floats, and stationary platforms, in addition to derived data from satellite observations. The Volunteer Observing Ship fleet is comprised of some 5,000 commercial ships. About 900 ships report marine meteorology observations at least 25 times per month. A subset of the volunteer ships routinely deploys expendable bathythermograph probes to measure upper-ocean temperatures to a depth of 750 meters; about 20,000 probes are deployed annually. An array of 1250 surface drifting buoys provides 30,000 sea surface temperature and surface air pressure reports per day. Surface currents are derived by tracking the drifter movements. A network of 375 moored buoys provides about 9000 reports of surface marine observations per day. The moored buoys are located offshore of several maritime nations and also span the tropical Pacific and Atlantic Oceans. Implementation of a tropical Indian Ocean moored array is now underway. The Indian Ocean array is planned to be completed by about 2012. Argo--a global array of profiling floats--provides profiles of ocean temperature and salinity to depths of 2000 meters. Each float reports via satellite once every 10 days. As of December 2007 the Argo floats program was reaching its design goal of 3000 floats.

Global Climate Observing System (GCOS)

The United States has been involved with GCOS since its inception. NOAA's National Climatic Data Center (NCDC) in Asheville, North Carolina, supports a number of GCOS data management activities and hosts the U.S. GCOS Program Office based in Silver Spring, Maryland [see http://www.ncdc. noaa.gov/oa/usgcos/index.htm]. This support fits in with a proactive process approach for GCOS implementation planning with the goal of obtaining a sustainable and robust GCOS observing network for international atmospheric, oceanographic, and terrestrial climate observing. The U.S. national program has taken a three-tiered approach to fostering the GCOS program. This approach involves providing support:

- Internationally to improve and enhance monitoring stations in developing nations which require assistance as identified by the international GCOS Atmospheric Observations Panel for Climate.
- Regionally for workshops and projects such as those in the Pacific Ocean region for ensuring a robust and sustainable GCOS observing program; and
- On a bilateral basis with nations that have entered into agreements with the United States on improving climate observing activities.

Meteorological surface-based networks, utilized for climate purposes, make observations of important climate factors; atmospheric profiles; and pollutant emissions, aerosols, and ozone. These surface-based networks are intended to provide the basic observational set needed to define the status and trends in climate of the world, and also to calibrate and validate satellite-based observations. NOAA's U.S. GCOS Program Office has committed to leading the way, in partnership with the GCOS Secretariat at the WMO, to facilitate improvements in the management and operation of GCOS and GCOS-related networks.

In general, GCOS performance measures used by NOAA in managing its international support are intended to gradually increase the quality and quantity of data from the GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN) over the next several years. The performance measures focus on observing system improvements in developing nations in Africa, South America, and the Pacific Islands. The support for developing nations has primarily been for retrofitting surface and upper-air observing stations that have up-to-now been silent, but yet are key to global climate monitoring activities. Countries that have received new equipment and expendables over the past three years include: Argentina, Armenia, Congo, Cook Islands, Costa Rica, Ecuador, Ivory Coast, Kenya, Maldives, Namibia, the Philippines, and Zimbabwe. The U.S. State Department has been instrumental in aiding in the establishment of regional GCOS maintenance facilities which have been established in the Pacific and the Caribbean. Another one is being planned for Southern and Eastern Africa in order to further the sustainability of the GCOS network in the developing nations of that region.

Additionally, for the GSN, the performance measure is the percent explained variance in mean annual temperature in the developing world. The long-term goal is 90 percent explained variance with a network of 75 stations. This will be accomplished by deploying new observing stations that meet the same stringent requirements as those in the U.S. Climate Reference Network. For the GUAN, the long-term objective is to increase the percent of GUAN sites in the developing world that meet GCOS reporting requirements (i.e., two soundings per day for 25 days in the month, each sounding with temperature/wind data up to 5 hPa and humidity data up to the tropopause). This will be accomplished by modernizing 75 existing GUAN stations. The long-term goal is to have 90 percent of the GUAN stations in the developing world meeting GCOS requirements. The U.S. GCOS Program, in conjunction with the GCOS Secretariat and other elements in NOAA, is working towards the development of a high-quality GCOS Atmospheric Reference Observations Network (GARON). Finally, support for the chemical constituent portion of GCOS, the Global Atmosphere Watch (GAW) program is part of the integrated GCOS support provided.

Global Data Processing and Forecasting System (GDPFS)

The purpose of GDPFS is to make available all processed information required for both real-time and non-real-time applications. GDPFS 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 GDPFS products which allow all countries to benefit from their participation in the WWW.

The GDPFS is organized as a three-level system. It consists of World Meteorological Centers (WMC), Regional/Specialized Meteorological Centers (RSMC), and National Meteorological Centers (NMC). Products of RSMCs can be used by members at the national level for further processing or interpretation to provide assistance or service to users. NMCs carry out GDPFS functions at the national level.

In general, real-time functions of the system involve preprocessing of data to include real-time quality control, analysis, and prognosis, and the 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, and 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.

RSMCs with geographical specialization include Algiers, Beijing, Bracknell, Brazilia, Buenos Aires, Cairo, Dakar, Darwin, Jeddah, Khabarovsk, Melbourne, Miami, Montreal, Moscow, Nairobi, New Delhi, Novosibirsk, Offenbach, Pretoria, Rome, Tashkent, Tokyo, Tunic/Casablanca, Washington and Wellington. RSMCs with specialization for tropical cyclone forecasting are: Miami - Hurricane Center, Nadi - Tropical Cyclone Center, New Delhi - Tropical Cyclone Center, Saint Denis, La ReUnion - Tropical Cyclone Center, Tokyo - western Pacific Typhoon Center, and Honolulu - central Pacific Typhoon Center. The European Center for Medium-Range Weather Forecasts (ECMWF) is an RSMC operated by the European community out of Bracknell, UK. The regional centers at Bracknell, Honolulu, Miami, Montreal, New Delhi, and Tokyo also 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. The RSMCs located at Beijing, Bracknell, Melbourne, Montreal, Obninsk, Tokyo, Toulouse, and Washington provide, upon request, atmosphere aerosol and chemical transport model products for environmental emergency responses.

Other WMO-designated specialized centers serve emerging development needs: African Center of Meteorological Applications for Development (ACMAD) - Niamey, Niger; ASEAN Specialized Meteorological Center (ASMC) - Singapore; Drought Monitoring Centers (DMC) - Nairobi, Kenya, and Harare, Zimbabwe; National Institute of Space Research - Sao Paulo, Brazil; National Center for Medium Range Weather Forecasting - New Delhi.

International Satellite Communication System (ISCS)

The World Area Forecast System (WAFS) has two centers (Washington and London) which are designated by the International Civil Aviation Organization (ICAO) as World Area Forecast Centers (WAFC). The dissemination of aeronautical information via global satellite broadcast began in 1995, through the International Satellite Communication System (ISCS). The United States provides the links to two of the three satellites specified in the system. The WAFS issue upper-level wind and temperature forecasts with global coverage and forecasts of weather elements defined by ICAO as significant.

The United States continues to support ten ISCS/WAFS workstations of the Regional Meteorological Telecommunication Network in the Caribbean and also supports the Caribbean weather website (www.caribweather.net).

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 international organizations, and environmental programs as decided by the WMO 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, referred to as the WMO Information System (WIS), 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).
- Upgrade of the GTS in the Indian Ocean Basin to facilitate real-time movement of tsunami and natural hazard warnings.
- 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. Planning is underway for eventual conversion of WEFAX to Low-Rate Information Transmission (LRIT) and Automatic Picture Transmission (APT) to Low Rate Picture Transmission (LRPT) formats with the advent of a new generation of satellites.

Voluntary Cooperation Program (VCP)

The WMO Voluntary Cooperation Program (VCP) is a technical cooperation program, managed by the WMO, focused on meeting the needs of member countries to implement WMO scientific and technical programs. The VCP endeavors to complement activities being implemented through national meteorological services and WMO trust-fund arrangements, and through other UN organizations such as United Nations Development Program (UNDP).

The United States participates in the WMO VCP with coordination assistance provided by NOAA's National Weather Service. Each year, the United States contributes nearly $2 million dollars to the VCP to support education and training for developing countries to strengthen their capacity in the sciences of meteorology and hydrology.

U.S. VCP funds provided assistance to developing countries to help develop and improve their WMO telecommunications infrastructure for tsunami and natural disaster warning networks. Through the NWS' National Centers for Environmental Prediction (NCEP), the U.S. VCP supports weather forecast training for the Americas and the Caribbean countries and climate prediction training for Africa. Additionally, in the Pacific, NCEP provides forecaster training for islanders, and new funding is now dedicated to working with regional associations to enhance communications by upgrading of Low-Rate Users Stations in the Island Developing States to provide access to meteorological satellite images in LRIT format for 17 Pacific Island countries and territories. The U.S. VCP will also support training programs in the Americas to advance satellite data applications and build capacity as part of the Earth Observations Partnerships of the Americas (EOPA) initiative.

# APPENDIX C
# PREVIOUS FEATURE ARTICLES

| Year | Edition | Title | Author |
|---|---|---|---|
| 2007 | FY 2008 | Hydrometeorology Products and Services: A Partnership in Public Safety | Mr. Donell Woods, OFCM<br>Mr. Robert Dumont, OFCM |
| 2006 | FY 2007 | Roadmap for Tropical Cyclone Research to Meet Operational Needs | Mr. Mark Welshinger, OFCM |
| 2005 | FY 2006 | Living With Wildland Fire in the Urban Environment | Ms. Mary M. Cairns, OFCM |
| 2004 | FY 2005 | The Rewards of Managing Weather-Related Risks | Mr. Samuel P. Williamson, OFCM |
| 2003 | FY 2004 | Weather and The Urban Environment: Meeting The Needs of Urban Communities | Ms. Margaret R. McCalla, OFCM |
| 2002 | FY 2003 | The Need For Weather Information For Surface Transportation: Keeping The Country Safe and On The Move | Ms. Mary M. Cairns, OFCM |
| 2001 | FY 2002 | Research to Operations: Bridging the Valley of Death | Mr. Robert Dumont, OFCM |
| 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<br>Dr. William Hooke, OAR, and<br>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<br>Mr. Andrew H. Horvitz, NWS<br>Mr. Arthur L. Booth, NOAA-EOSDIS |

| Year | Edition | Title | Author |
|---|---|---|---|
| 1993 | FY 1994 | Training and Professional Development in the Modernized Weather Services | Mr. Eli Jacks, NWS<br>Mr. LeRoy Spayd, NWS |
| 1992 | FY 1993 | Mesoscale Meteorology | Mr. Floyd F. Hauth, OFCM |
| 1991 | FY 1992 | Some Recent Developments in Lightning Mapping Systems | Dr. Donald R. MacGorman, NOAA<br>Dr. Frederick R. Mosher, NOAA<br>Ms. Jan S. Lewis, NOAA |
| 1990 | FY 1991 | The Next Generation Weather Radar - A System for Locating and Tracking Severe Weather | Mr. E. Don Sarreals, NEXRAD JSPO |
| 1989 | FY 1990 | Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service | Verbatim reproduction of a plan required by Congress and submitted by DOC and OMB |
| 1988 | FY 1989 | Supercomputers for Meteorological Services and Supporting Research | (Source or author unknown) |

# APPENDIX D
# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| 3D-VAR | Three Dimensional VARiational (DOD) |
| 4DWX | Four Dimensional Weather (DOD) |
| | |
| AA | Active Army |
| AAO | Amarillo Area Office (DOE) |
| AASHTO | American Association of State Highway and Transportation Officials (FHWA) |
| AAU | Alaskan Aviation Unit (NOAA/NCEP) |
| AB | Authorization Basis |
| ABCS | Army Battle Command System (DOD) |
| ABFM | Airborne Field Mill (NASA) |
| ABL | Airborne Laser (DOD) |
| ABLE | Atmospheric Boundary Layer Experiment (DOE) |
| AC | Active Component (DOD) |
| AC&A | Atmospheric Chemistry and Aerosols (DOE) |
| ACARS | ARINC Communication Addressing and Reporting System |
| ACD | Atmospheric Chemistry Division (DOE) |
| ACE | Aviation Combat Element (DOD) |
| ACE-IDS | ASOS Controller Equipment - Information Display System (FAA) |
| ACIS | Applied Climate Information System (USDA) |
| ACP | Atmospheric Chemistry Program (DOE) |
| ACSG | Atmospheric and Climate Sciences Group (DOE) |
| ADA | Atmospheric Decision Aid (DOD) |
| ADAPT | Atmospheric Data Assimilation and Parameterization Tool (DOE) |
| ADAS | AWOS/ASOS Data Acquisition System (FAA) |
| ADEOS | Advanced Earth Observing System (NASA) |
| AEC | Atomic Energy Commission (DOE) |
| AEP | Atmospheric Emergency Preparedness (DOE) |
| AESS | Allied Environmental Support System (DOD) |
| AF | Air Force |
| AFB | Air Force Base |
| AFCCC | Air Force Combat Climatology Center |
| AFCWC | Air Force Combat Weather Center |
| AFFSA | Air Force Flight Standards Agency |
| AFGS | Aviation Forecast Gridded System |
| AFJI | Air Force Joint Instruction |
| AFR | Air Force Reserve |
| 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 |
| AFWWS | Air Force Weather Weapon System |
| AF/XOO | Air Force Director of Operations and Training (DOD) |
| AF/XO | Air and Space Deputy Chief of Staff for Air and Space Operations (DOD) |
| AF/XOO-W | Air Force Director of Weather |
| AGFS | Aviation Gridded Forecast System (FAA) |
| AGRIMET | A conjunction of the words “agricultural” and “meteorology”, is a satellite-based network of automated agricultural weather stations operated and maintained by the U.S. Bureau of Reclamation (DOI) |
| AHPS | Advanced Hydrologic Prediction Services (NOAA/NWS) |
| AI | Aircraft Icing (NASA) |
| AIP | Airport Improvement Program (FAA) |

| | |
|---|---|
| AIRMAP | Atmospheric Investigation Regional Modeling, Analysis, and Prediction (NOAA/OAR) |
| AIRMoN | Atmospheric Integrated Research Monitoring Network (NOAA/OAR) |
| AIRS | Atmospheric Infrared Sounder (NASA) |
| AL | Aeronomy Laboratory (NOAA/OAR) |
| ALDARS | Automated Lightning Detection and Reporting System (FAA) |
| ALOHA | Areal Locations of Hazardous Atmospheres (a transport and dispersion code) |
| ALOO | Albuquerque Operations Office |
| AMC | Army Materiel Command |
| AMDAR | Aircraft Meteorological Data Relay (WWP) |
| AMIS | Automated Meteorological Information System (DOD) |
| AMPS | Automated Meteorological Profiling System (NASA) |
| AMOS | Automated Meteorological Observing System (DOD) |
| AMS | Acquisition Management System (FAA) |
| | American Meteorological Society |
| AMSR-E | Advanced Microwave Sounding Radiometer |
| AMSU | Advanced Microwave Sounding Unit |
| AMU | Applied Meteorology Unit (NASA) |
| ANG | Air National Guard (DOD) |
| ANL | Argonne National Laboratory (DOE) |
| AOC | Aircraft Operations Center (NOAA) |
| | Air and Space Operations Center (DOD) |
| AOML | Atlantic Oceanographic and Meteorological Laboratory (NOAA/ERL) |
| AOR | Area of Responsibility (DOD) |
| AOT | Aerosol Optical Thickness (NOAA/NESDIS) |
| APGEMS | Air Pollutant Graphical Environmental Monitoring System |
| APS | Aerosol Polarimetry Sensor (APS) |
| APT | Automatic Picture Transmission (NOAA/NESDIS) |
| AQG | Air Quality Group (DOE) |
| AR | Army Regulation |
| ARAC | Atmospheric Release Advisory Capability (DOE) |
| ARCS | Atmospheric Radiation CART Sites (NOAA/OAR) |
| ARG | Accident Response Group (DOE) |
| ARGO | Global Array of Profiling Floats (NOAA/OAR) |
| ARGOS | French Satellite Data Collection System |
| ARINC | Aeronautical Radio Incorporated |
| ARL | Army Research Laboratory |
| | Air Resources Laboratory (NOAA and DOE) |
| ARM | Atmospheric Radiation Monitoring (DOE) |
| ARNG | Army National Guard |
| ARO | Army Research Office |
| ARS | Agricultural Research Service (USDA) |
| | Air Traffic System Requirements Service (FAA) |
| | Atmospheric Research Section (DOE) |
| ARSL | Atmospheric Remote Sensing Laboratory |
| 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 (DOD) |
| ARW | Aviation Weather Directorate (FAA) |
| ASCAT | Advanced Scatterometer |
| ASD | Atmospheric Sciences Division (DOE) |
| ASDAR | Aircraft to Satellite Data Relay |
| ASNE MSEA | Air and Space Natural Environment Modeling and Simulation Executive Agent (DOD) |
| ASOG | Air Support Operations Group (DOD) |
| ASOS | Automated Surface Observing System |
| | Air Support Operations Squadron (DOD) |
| ASP | Atmospheric Science Program (DOE) |

| | |
|---|---|
| ASR | Airport Surveillance Radar (FAA) |
| ATC | Air Traffic Control (FAA) |
| ATCCS | Army Tactical Command and Control System |
| ATD | Atmospheric Turbulence and Diffusion |
| ATDD | Atmospheric Turbulence and Diffusion Division (NOAA/ARL) |
| ATEC | Army Test and Evaluation Command |
| ATG | Atmospheric Technologies Group (DOE) |
| ATLAS | Autonomous Temperature Line Acquisition System (NOAA/OAR) |
| ATMS | Advanced Technology Microwave Sounder |
| ATO | Air Traffic Organization (FAA) |
| | Air Tasking Order (DOD) |
| ATOS | Appalachian Tropospheric Ozone Study (NOAA/AOC) |
| ATWIS | Advanced Transportation Weather Information System (FHWA) |
| AVHRR | Advanced Very High Resolution Radiometer (NOAA) |
| AVO | Alaskan Volcano Observatory (DOI/USGS) |
| AVP | Advanced Vehicle Technologies Program (FTA) |
| AWARDS | Agricultural Water Resources Decision Support (DOI/BUREC) |
| AWC | Aviation Weather Center (NOAA/NCEP) |
| AWIPS | Advanced Weather Interactive Processing System (NOAA) |
| AWIS | Automated Weather Information System |
| AWN | Automated Weather Network (DOD) |
| AWOS | Automated Weather Observing System (FAA) |
| AWR | Aviation Weather Research (FAA) |
| AWSS | Aviation Weather Sensor System (FAA) |
| AWTT | Aviation Weather Technology Transfer (FAA) |
| BAMP | Breton Aerometric Monitoring Program (DOI) |
| BASC | Board on Atmospheric Sciences and Climate |
| BCTP | Battle Command Training Program (DOD) |
| BE | Battlefield Environment (DOD) |
| BER | Biological and Environmental Research (DOE) |
| BFA | Battlefield Functional Areas (DOD) |
| BIO | Basis for Interim Operations (DOE) |
| BLM | Bureau of Land Management (DOI) |
| BMDO | Ballistic Missile Defense Office (DOD) |
| 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, Computers, and Intelligence (DOD) |
| CAAM | Computer Assisted Artillery Meteorology (DOD) |
| CAC | Combined Arms Center (DOD) |
| CAIB | Columbia Accident Investigation Board |
| CALJET | California Land-falling Jets Experiment (NOAA/OAR) |
| CAMEO | Computer Aided Management of Emergency Operations |
| CAMEX | Convective and Moisture Experiment (NASA) |
| CAO | Carlsbad Area Office |
| CAP | Civil Air Patrol |
| CAP88-PC | Clean Air Act Assessment Package-1988 - Personal Computer (DOE) |
| CAPARS | Computer-Assisted Protective Action Recommendation System (DOE) |
| CARDS | Comprehensive Aerological Reference Data Set (NOAA/NCDC) |
| CARS | Condition Acquisition and Reporting System (FHWA) |
| CART | Clouds and Radiation Testbed (DOE) |
| CASPER | Computer Aided System For Planning Efficient Routes (FHWA) |
| CAST | Commercial Aviation Safety Team (FAA) |
| CAT | Clear Air Turbulence |
| CAWIS | Committee for Automated Weather Information Systems (OFCM) |

| | |
|---|---|
| CBFO | Carlsbad Field Office |
| CBIRF | Chemical Biological Incident Response Force (DOD) |
| CBAP | Catastrophic Backup Action Plan |
| CBNP | Chemical Biological Non-Proliferation Program (DOE) |
| | Chemical Biological National Security Program (DOE) |
| CBOFS | Chesapeake Bay Oceanographic Forecasting System (NOAA/NOS) |
| CBRNE | Chemical, Biological, Radiological, Nuclear, or High-Yield Explosive (DOD) |
| CBS | Commission on Basic Services (WWP) |
| CCAFS | Cape Canaveral Air Force Station |
| CCCM | Climate and Carbon Cycle Modeling (DOE) |
| CCM | Community Climate Model used at LANL (DOE) |
| CCMC | Community Coordinated Modeling Center (DOD) |
| CCMS | Committee on the Challenges of Modern Society (EPA) |
| CDA | Command and Data Acquisition |
| CDF | Cloud Depiction and Forecasting (DOD) |
| CDFS | Cloud Depiction and Forecast System (DOD) |
| CDPHE | Colorado Department of Public Health and Environment (DOE) |
| CECOM | Communications and Electronics Command (DOD) |
| 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) |
| CFD | Computational Fluid Dynamics |
| CFIT | Controlled Flight Into Terrain (NASA) |
| CFR | Code of Federal Regulations (DOE) |
| CGSC | Command and General Staff College (DOD) |
| CHAMMP | Computer Hardware Advanced Mathematics and Model Physics (DOE) |
| CHARM | An Atmospheric Transport and Dispersion Model |
| CIASTA | Cooperative Institute for Atmospheric Studies and Terrestrial Applications (NOAA/OAR) |
| CICE | Sea Ice Code at LANL |
| CIDE | Communications Interfaces and Data Exchange (OFCM) |
| CIOS | Committee for Integrated Observing Systems (OFCM) |
| CIRES | Cooperative Institute for Research in Environmental Sciences |
| CIWS | Corridor Integrated Weather System (FAA) |
| CLASS | Comprehensive Large Array-Data Stewardship System (NOAA/NESDIS) |
| CLIVAR-GEWEX | Climate Variability and Predictability - Global Energy and Water Cycle Experiment |
| CLIVAR-VAMOS | Climate Variability and Predictability - Variability and Predictability of the American Monsoon System |
| C-MAN | Coastal-Marine Automated Network |
| CMAQ | Community Multi-scale Air Quality (EPA) |
| CMDL | Climate Monitoring and Diagnostics Laboratory (NOAA/OAR) |
| CME | Coronal Mass Ejection |
| CMFC | Coordinating METOC Forecast Center (DOD) |
| CMIS | Conical Scanning Microwave Imager Sounder |
| CMR | Central Monitoring Room |
| CMS | Central Monitoring System |
| COADS | Comprehensive Ocean-Atmosphere Data Set (NOAA/NCDC) |
| COAMPS | Coupled Ocean-Atmosphere Mesoscale Prediction System |
| COARE | Coupled Ocean-Atmosphere Response Experiment |
| COE | Corps of Engineers (DOD) |
| COMET | Cooperative Program for Operational Meteorology, Education and Training |
| CONUS | Continental United States (DOD) |
| CONUSA | Continental United States Armies (DOD) |
| 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 (DOD) |
| COTS | Commercial Off-the-Shelf |

| | |
|---|---|
| CPC | Climate Prediction Center (NOAA/NCEP) |
| CPHC | Central Pacific Hurricane Center (NOAA/NCEP) |
| CRADA | Cooperative Research and Development Agreement |
| CrIS | Cross-track Infrared Sounder |
| CRN | Climate Reference Network (NOAA) |
| CRREL | Cold Regions Research and Engineering Laboratory (DOD) |
| CS | Climate Services |
| 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) |
| CSW | Committee for Space Weather (OFCM) |
| CTA | Common Table of Allowances (DOD) |
| CTBT | Comprehensive Test Ban Treaty (DOE) |
| CWS | Combat Weather Squadron (DOD) |
| CWSU | Center Weather Service Unit (FAA) |
| CWT | Combat Weather Team (DOD) |
| CXD | Combined X-ray Dosimeter (DOE) |
| CY | Calendar Year |
| | |
| DAC | Data Assembly Center (NOAA/OAR) |
| DAMPS | Distributed Atmospheric Modeling Prediction System (DOD) |
| DAT | Department of Advanced Technology (DOE) |
| DCO | Data Collection Office (NOAA/NWS) |
| DCP | Data Collection Package |
| | Data Collection Platform (DOI) |
| DCS | Data Collection System (NOAA/NESDIS) |
| DEPSCoR | Experimental Program to Stimulate Competitive Research (DOD) |
| DGPS | Differential Global Positioning System (USGS) |
| DHS | Department of Homeland Security |
| DIS | Decision and Information Sciences (DOE) |
| DISS | Digital Ionospheric Sounding System (DOD) |
| DMCC | DOE Meteorological Coordinating Council (DOE) |
| DMS | Dynamic Message Sign (FHWA) |
| DMSO | Defense Modeling and Simulation Office (DOD) |
| DMSP | Defense Meteorological Satellite Program (DOD) |
| DNT | Dinitrotoluene (DOE) |
| DOA | Department of Agriculture |
| DOC | Department of Commerce |
| DOCS | DOE Center for Research on Ocean Carbon Sequestration |
| DOD | Department of Defense |
| DOE | Department of Energy |
| DOI | Department of the Interior |
| DOMSAT | Domestic Communications Satellite (DOI) |
| DOS | Department of State |
| DOT | Department of Transportation |
| DRA | Desert Rock Meteorological Observatory at NTS (DOE) |
| DREC | Delta Research Extension Center (USDA) |
| DRGS | Direct Readout Ground Stations (DOI) |
| DRI | Desert Research Institute (DOE) |
| DRWP | Doppler Radar Wind Profiler (NASA) |
| DSA | Documented Safety Analysis |
| DSTL | Defense Science and Technology Laboratory |
| DTC | Developmental Test Command (DOD) |
| DTED | Digital Terrain Elevation Data (DOD) |
| DTRA | Defense Threat Reduction Agency |
| DTSS | Digital Topographic Support System (DOD) |
| DUAT | Direct User Access Terminal (FAA) |

| | |
|---|---|
| DURIP | Defense University Research Instrumentation Program (DOD) |
| | |
| EAC | Echelon Above Corps (DOD) |
| EAD | Environmental Assessment Division (DOE) |
| EBID | Environmental Biology and Instrumentation Division (DOE) |
| 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) |
| EED | Energy and Environment Division |
| EERE | Office of Energy Efficiency and Renewable Energy (DOE) |
| EH | Environmental Health |
| ELV | Expendable Launch Vehicle (NASA) |
| EM | Office of Environmental Management (DOE) |
| EMC | Environmental Modeling Center (NOAA/NCEP) |
| | European Modeling Center (NOAA/NCEP) |
| EM&H | Environmental Monitoring & Hydrology |
| EMI SIG | Emergency Management Issues Special Interest Group |
| EMP | Environmental Meteorology Program (DOE) |
| EMS | Environmental Monitoring Section (DOE) |
| EMSL | Environemtal and Molecular Sciences Labratory |
| ENSO | El Niño-Southern Oscillation |
| EO | Electro-optical |
| | Earth Observation (NASA) |
| EOC | Emergency Operations Center |
| EOS | Earth Observing System (NASA) |
| EOSDIS | EOS Data and Information System (NASA) |
| EPA | Environmental Protection Agency |
| EPD | Environmental Protection Department (DOE) |
| EPIC | Equatorial Pacific Investigation of Climate (NOAA/AOC) |
| EPR | Emergency Preparedness and Response Directorate (FEMA) |
| E-PIREPS | Electronic Pilot Reports (FAA) |
| EP/RD | Environmental Protection/Restoration Department (DOE) |
| EPZ | Emergency Planning Zone (DOE) |
| ER | Eastern Range (NASA) |
| | Environmental Research (DOE) |
| ERBS | Earth Radiation Budget Satellite (NASA) |
| ERC | Extended Research Checkout |
| ERDA | Energy Research and Development Administration (DOE) |
| ERDAS | Eastern Range Dispersion Assessment System (NASA) |
| ERDC | Engineering Research and Development Center (DOD) |
| ERL | Environmental Research Laboratories (NOAA) |
| ESC | Environmental Systems Corporation |
| ESD/IPC | Environmental Satellite Distribution/Interactive Processing Center (NOAA/NESDIS) |
| ESE | Earth Science Enterprise (NASA) |
| ESP | Energy Spectrometer for Particles (DOE) |
| | Ensemble Streamflow Prediction (NWS) |
| ESS | Environmental Sensor Station (FHWA) |
| ESSP | Earth System Science Pathfinders (NASA) |
| ETIS | Evacuation Traffic Information System (FHWA) |
| ETL | Environmental Technology Laboratory (NOAA/OAR) |
| ETOS | East Tennessee Ozone Study (NOAA/OAR) |
| ETTP | East Tennessee Technology Park (DOE) |
| ET Toolbox | Evapotranspiration Toolbox (DOI) |
| EUMETSAT | European Organization for the Exploitation of Meteorological Satellites |
| EUSA | Eighth U.S. Army |
| EUV | Extreme Ultraviolet |
| EWR | Ellason Weather Radar (DOD) |

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|---|---|
| FAA | Federal Aviation Administration |
| FALOP | Forward Area Limited Observing Program (DOD) |
| FAS | Foreign Agricultural Service (USDA) |
| FBA | Fire Behavior Analysts (DOI) |
| FCC | Federal Communications Commission |
| FCCC | Framework Convention on Climate Change (DOS) |
| FCMSSR | Federal Committee for Meteorological Services and Supporting Research (OFCM) |
| FCS | Future Combat System (DOD) |
| FDD | First Digitized Division (DOD) |
| FDIC | Force Development and Integration Center (DOD) |
| FEM3MP | LLNL finite element model (DOE) |
| FEMA | Federal Emergency Management Agency |
| FHWA | Federal Highway Administration |
| FIRETEC | Fire Code at LANL (DOE) |
| FIRST | FAA Icing Remote Sensor Testbed (NOAA/OAR) |
| FIS | Flight Information System (FAA) |
| FITL | Forecaster-in-the-Loop (DOD) |
| 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 (DOD) |
| FOA | Field Operating Agency (DOD) |
| FORSCOM | U.S. Army Forces Command |
| FOV | Field of vision |
| FR | Flight Rules |
| 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) |
| FRWS | Fire RAWS (DOI) |
| FS-21 | Forecasting System 21$^{st}$ Century (DOD) |
| FS | Forest Service (USDA) |
| FSA | Farm Services Agency (USDA) |
| FSL | Forecast Systems Laboratory (NOAA/OAR) |
| FSR | Forest Service Research (USDA) |
| FTA | Federal Transit Administration |
| FTE | Full-time Equivalent |
| FTP | File Transfer Protocol |
| FU | Forecast Unit |
| FWS | Fish and Wildlife Service (DOI) |
| FY | Fiscal year |
| | |
| G-IV | Gulfstream IV (NOAA) |
| GAA | GOES Active Archive (NOAA/NESDIS) |
| GAC | Global Area Coverage |
| GACC | Geographic Areas Coordination Center (DOI) |
| GACP | Global Aerosol Climatology Project (NASA) |
| GAIM | Global Assimilation of Ionospheric Measurements (DOD) |
| 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 |

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|---|---|
| GDPC | Global Data Processing Centers (WWP) |
| GDPFS | Global Data Processing and Forecast System (WWP) |
| GEM | Generation of weather Elements for Multiple (USDA) |
| GEOSAR | Geostationary Earth Orbit Search and Rescue (NOAA/NESDIS) |
| GEOSS | Global Earth Observation Systems of Systems (WWP) |
| 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) |
| GLOFS | Great Lakes Operational Forecast System |
| GLONASS | Global Navigation Satellite System (NOAA/NESDIS) |
| GMS | Geostationary Meteorological Satellite-Japan (WWP) |
| GMSRA | GOES Multi-Spectral Rainfall Algorithms (NOAA/NESDIS) |
| GMU | George Mason University |
| 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 |
| 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 Profile Project |
| GTWAPS | Global Theater Weather Analysis and Prediction System (DOD) |
| GUAN | GCOS Upper Air Network (WWP) |
| | |
| HAF | Headquarters Air Force (DOD) |
| HaL | Hurricanes at Landfall (NOAA/OAR) |
| HAR | Highway Advisory Radio (FHWA) |
| HARM | Hazardous Atmospheric Release Model (NOAA/OAR) |
| HAZMET | Hazardous Material (FHWA) |
| HCRS | Highway Closure and Restriction System (FHWA) |
| HDB | Hydrologic DataBase (DOI) |
| HELSTF | High Energy Laser System Test Facility (DOD) |
| HF | High Frequency |
| HFRB | High Frequency Regional Broadcast |
| HIGRAD | Transport and Dispersion Model at LANL (DOE) |
| 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 (DOD) |
| HPC | Hydrometeorological Prediction Center (NOAA/NCEP) |
| HPCC | High Performance Computing and Communications |
| HRAP | Hydrologic Rainfall Analysis Project (DOI) |
| HRD | Hurricane Research Division (NOAA/ERL) |
| HRPT | High Resolution Picture Transmission (NOAA/NESDIS) |
| HS | Health Safety and Security |
| HSA | Hydrologic Service Area (NOAA/NWS) |
| HSM | Heat Stress Monitor (DOD) |
| HYDROMET | A network of automated hydrologic and meteorologic monitoring stations located throughout the Pacific Northwest (DOI) |

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|---|---|
| HYSPLIT | Hybrid Single Particle Lagrangian Integrated Trajectory (NOAA/OAR) |
| HUD | Head-up display (NASA) |
| | |
| IA | Interagency Agreement |
| IAMS | Initial Attack Management System (DOI) |
| IAS | International Airspace System (NOAA/NWS) |
| IAV | Interim Armored Vehicle (DOD) |
| IBCT | Interim Brigade Combat Teams (DOD) |
| ICAO | International Civil Aviation Organization |
| LCC | Launch Commit Criteria |
| ICMSSR | Interdepartmental Committee for Meteorological Services and Supporting Research (OFCM) |
| ICSU | International Council of Scientific Unions |
| IDCS | International Data Collection System (WWP) |
| IEW | Intelligence and Electronic Warfare (DOD) |
| IFEX | Intensity Forecast Experiment |
| IFFA | Interactive Flash Flood Analyzer (NOAA/NESDIS) |
| IGBP | International Geosphere Biosphere Programme (WWP) |
| IHC | Interdepartmental Hurricane Conference (OFCM) |
| IIP | International Ice Patrol (USCG) |
| IMA | Individual Mobilization Augmentee (DOD) |
| IMAAC | Interagency Modeling and Atmospheric Assessment Center |
| IMDES | Interdepartmental Meteorological Data Exchange System |
| IMETS | Integrated Meteorological System (DOD) |
| | Incident Meteorologists (NOAA/NWS) |
| IMPROVE | Interagency Monitoring of Protected Visual Environments (DOI) |
| INEEL | Idaho National Engineering and Environmental Laboratory (DOE) |
| INL | Idaho National Laboratory |
| INS | Incidents of National Significance |
| INSAT | India's National Satellite (WWP) |
| IOC | Intergovernmental Oceanographic Commission (WWP) |
| IPB | Intelligence Preparation of the Battlespace (DOD) |
| IPCC | Intergovernmental Panel on Climate Change (WWP/DOS) |
| IPEX | Intermountain Precipitation Experiment (NOAA/OAR) |
| IPO | Integrated Program Office |
| IR | Infrared |
| IRCCSI | Institue for research on Climate Change & Its Societal Impacts |
| IRTSS | Infrared Target Scene Simulation Software (DOD) |
| ISCCP | International Satellite Cloud Climatology Program (NOAA/NESDIS) |
| ISES | International Space Environment Service (NOAA/OAR) |
| ISIS | Integrated Solar Irradiance Study (NOAA/OAR) |
| ISMS | Integrated Safety Management System (DOE) |
| ISS | International Space Station |
| ISTEA | Intermodal Surface Transportation Efficiency Act (FHWA) |
| IT | Information Technology |
| ITCT | Intercontinental Transport and Chemical Transformation (NOAA/OAR) |
| ITCZ | Inter-tropical convergence zone |
| ITS | Intelligent Transportation System (FHWA) |
| ITS-JPO | ITS Joint Program Office (FHWA) |
| IT-RD | Information Technology Research and Development (EPA) |
| ITWS | Integrated Terminal Weather System (FAA) |
| IWEDA | Integrated Weather Effects Decision Aid (DOD) |
| IWGCCST | Interagency Working Group on Climate Change Science and Technology (DOS) |
| IWRS | Improved Weather Reconnaissance System (OFCM) |
| IWRPC | Improved Weather Reconnaissance System Program Council (OFCM) |
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| JAAWIN | Joint Air Force-Army Weather Information Network (DOD) |
| JAG | Joint Action Group |
| JAG/OCM | Joint Action Group for Operational Community Modeling |

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|---|---|
| JASL | Joint Archive for Sea Level |
| JAWF | Joint Agricultural Weather Facility (USDA) |
| JCOMM | Joint Commission for Oceanographic and Marine Meteorology (WWP) |
| JCS | Joint Chiefs of Staff (DOD) |
| JCSDA | Joint Center for Satellite Data Assimilation (NOAA/NCEP) |
| JET | Joint Environmental Toolkit (DOD) |
| JGOFS | Joint Global Ocean Flux Study |
| JHT | Joint Hurricane Testbed (NOAA/OAR) |
| JMDB | Joint METOC Database (DOD) |
| JMFU | Joint METOC Forecast Unit (DOD) |
| JMIB | Joint METOC Interoperability Board (DOD) |
| JMIST | Joint METSAT Imagery, Software, and Terminals (DOD) |
| JMV | Joint METOC Viewer (DOD) |
| JPL | Jet Propulsion Laboratory (NASA) |
| JSAT | Joint Safety Analysis Team (FAA) |
| JSIT | Joint Safety Implementation Team (FAA) |
| JSC | Johnson Space Center (NASA) |
| JSCP | Joint Strategic Capabilities Plan (DOD) |
| JTWC | Joint Typhoon Warning Center (DOD) |
| JWIS | Joint Weather Impacts System (DOD) |
| KAO | Kirtland Area Office |
| KDFOC | LLNL Fallout Model |
| KLC | Kodiak Launch Center (NASA) |
| KM | Kilometer |
| KSC | Kennedy Space Center (NASA) |
| 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 Laboratory (DOE) |
| LAPS | Local Analysis and Prediction System (NOAA/FSL) |
| LBNL | Lawrence Berkley National Laboratory |
| LDAR | Lightning Detection and Ranging |
| LDCM | Landsat Data Continuity Mission (NASA) |
| LDIS | Local Data Integration System (NASA) |
| LEO | Low Earth Orbit |
| LLCC | Lightning Launch Commit Criteria (NASA) |
| LLNL | Lawrence Livermore National Laboratory (DOE) |
| LLWAS | Low Level Wind Shear Alert System (FAA) |
| LLWAS-RS | LLWAS-Relocation/Sustainment (FAA) |
| LODI | Transport and Dispersion Model at LLNL (DOE) |
| LRGS | Local Readout Ground Stations (DOI) |
| LSD | Laboratory Services Division |
| LSM | Land Surface Model (DOD) |
| LV | Launch Vehicle |
| LWS | Living With A Star (NASA) |
| M2M | Machine-to-Machine |
| MACOM | Major Army Command |
| MAGTF | Marine Air Ground Task Force |
| MAJCOM | Major Command (DOD) |
| MAW | Marine Aircraft Wing |
| MB | Millibars |
| MC | Meteorological Codes |
| MCAF | Marine Corps Air Facilities |
| MCAS | Marine Corps Air Station |

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|---|---|
| MCCDC | Marine Corps Combat Development Command (DOD) |
| MCD | Mesoscale Discussions (NOAA/NWS) |
| MCO | Maintenance and Construction Operations (FHWA) |
| MCS | Mesoscale Convective System (NOAA/OAR) |
| MCSP | Meteorological and Climate Services Project |
| MCWP | Marine Corps Warfighting Publication (DOD) |
| MDIFF | Transport and Dispersion Code at INEEL (DOE) |
| MDCRS | Meteorological Data Communications and Reporting System (WWP) |
| MDSS | Maintenance Decision Support System (FHWA) |
| MeaPRS | MCS Electrification and Polarimetric Radar Study (NOAA/OAR) |
| MEDA | Meteorological Data System |
| MEF | Mission Execution Forecast (DOD) |
| MEPED | Medium Energy Proton and Electron Detector (NOAA/NESDIS) |
| MES | Marine Environmental Services (OFCM) |
| MET | Mobile Environmental Teams (DOD) |
| | Meteorological Teams (DOD) |
| METMF | Meteorological Mobile Facility (DOD) |
| METOC | Meteorological and Oceanographic (DOD) |
| METSAT | Meteorological Satellite |
| MHS | Microwave Humidity Sounder (NOAA/NESDIS) |
| MHz | Megahertz |
| MIMS | Multimedia Integrated Modeling System (EPA) |
| MM5 | Mesoscale Meteorological Model-Version 5.0 (DOD) |
| MME | Mobile Meteorological Equipment (OFCM) |
| MMS | Meteorological Measuring System (DOD) |
| | Mineral Management Service (DOI) |
| | Modular Modeling System (DOI) |
| MMS-P | Meteorological Measuring System-Profiler (DOD) |
| MOA | Memorandum of Agreement |
| MOBY | Marine Optical Buoy (NOAA/NESDIS) |
| MOCE | Marine Optical Characterization Experiment (NOAA/NESDIS) |
| MODIS | Moderate Resolution Imaging Spectrometer (NASA) |
| MOS | Model Output Statistics |
| MP | Mission Planning (DOD) |
| MPA | Magnetospheric Plasma Analyzer (DOE) |
| MPC | Marine Prediction Center (NOAA/NCEP) |
| MS | Monitoring the Stratosphere (OFCM) |
| MSFC | Marshall Space Flight Center (NASA) |
| MSL | Mean Sea Level |
| MSS | Meteorological Sounding System (NASA) |
| MST | Meteorological Support Teams (DOD) |
| MSU | Microwave Sounding Unit (NOAA/NESDIS) |
| MTI | Multi-spectal Thermal Imager |
| MTN | Main Telecommunications Network (WWP) |
| MTOE | Modified Table of Organization and Equipment (DOD) |
| MTPE | Mission to Planet Earth (NASA) |
| MTSAT | Multi-functional Transport Satellite |
| MWSS | Marine Wing Support Squadron |
| MW | Microwave |
| N511 | National 511-Traveler Information Service (FHWA) |
| NADIN | National Airspace Data Interchange Network (FAA) |
| NAF | Numbered Air Force |
| NAME | North American Monsoon Experiment |
| NAMIS | NATO Automated Meteorological Information System (DOD) |
| NMAO | NOAA Marine and Aviation Operations |
| NAP | Non-insured Crop Disaster Assistance Program (USDA) |

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|---|---|
| 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 |
| NASS | National Agricultural Statistics Service (USDA) |
| NATCOM | National Communications Center (FAA) |
| NATO | North Atlantic Treaty Organization (DOD, EPA) |
| 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 |
| NCA | National Command Authority (DOD) |
| NCAR | National Center for Atmospheric Research |
| NCAS | NOAA Center for Atmospheric Sciences |
| NCDC | National Climatic Data Center (NOAA/NESDIS) |
| NCEP | National Centers for Environmental Prediction (NOAA/NWS) |
| NCO | NCEP Central Operations (NOAA/NCEP) |
| | Non-commissioned officer (DOD) |
| NDBC | National Data Buoy Center (NOAA/NWS) |
| NDGPS | Nationwide Differiental Global Positioning System |
| NDI | Non-developmental item |
| NDOP | National Digital Orthoquad Program (USDA) |
| NDRI | Natural Disaster Reduction Initiative (NOAA) |
| NDVI | Normalized Difference Vegetation Index (NOAA/NESDIS) |
| NEAQS | New England Air Quality Study |
| NEMP | Non-radiological Environmental Monitoring Program |
| NEPA | National Environmental Policy Act |
| NERON | NOAA's Environmental Real-Time Observation Network |
| 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) |
| NETRAD | Networked Radars |
| 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) |
| NGST | Northrup Grumman Space Technology |
| NHC | National Hurricane Center (NOAA/NCEP) |
| NHI | National Highway Institute (FHWA) |
| NHOP | National Hurricane Operations Plan (OFCM) |
| NIC | National Ice Center (DOT/USCG) |
| | National Intelligence Community (DOD) |
| NIFC | National Interagency Fire Center (DOI) |
| NIPRNET | Non-secure Internet Protocol Router Network (DOD) |
| NIRT | Nuclear Incident Response Team |
| NIST | National Institute of Standards and Technology (DOC) |
| NITES | Navy Integrated Tactical Environmental Subsystem |
| NLDN | National Lightning Detection Network (FAA) |

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|---|---|
| NMC | National Meteorological Center(s) (WWP) |
| NMHS | National Meteorological and Hydrological Services (WWP) |
| NMOC | Naval Meteorology and Oceanography Command |
| NMP | New Millennium Program (NASA) |
| NMS | National Military Strategy (DOD) |
| NMTN | National Meteorological Telecommunications Network (WWP) |
| NNDC | NOAA National Data Center (NOAA/NESDIS) |
| NNSA | National Nuclear Security Administration (DOE) |
| NNSA/NSO | National Nuclear Security Administration/Nevada Site Office (DOE) |
| NOAA | National Oceanic and Atmospheric Administration |
| NOCMP | National Operational Coastal Modeling Program |
| NODC | National Oceanographic Data Center (NOAA/NESDIS) |
| NODDS | Navy Oceanographic Data Distribution System |
| NOGAPS | Navy Operational Global Atmospheric Prediction System |
| NOHRSC | National Operational Hydrologic Remote Sensing Center |
| NOS | National Ocean Service (NOAA) |
| NOTAMS | Notices to Airmen (FAA) |
| NOWS | NVG Operations Weather Software (DOD) |
| NPDES | National Pollutant Discharge Elimination System (DOE) |
| 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) |
| NRI | National Research Initiative (USDA) |
| NRL | Naval Research Laboratory |
| NRO | National Reconnaissance Office (DOD) |
| NRP | National Response Plan |
| NRVR | New Generation Runway Visual Range (FAA) |
| NSC | National Security Complex |
| NSF | National Science Foundation |
| NSIDC | National Snow and Ice Data Center (NOAA) |
| NSO | Nevada Site Office (DOE) |
| NSS | National Security Strategy (DOD) |
| NSSE | National Special Security Events |
| NSSL | National Severe Storms Laboratory (NOAA) |
| NSTC | National Science and Technology Council |
| NSTEP | National Strategic Training and Education Plan (NOAA/NWS) |
| NSWP | National Space Weather Program (OFCM) |
| NTCIP | National Transportation Communications for ITS Protocol (FHWA) |
| N-TFS | New Tactical Forecast System (DOD) |
| NTIS | National Technical Information Service |
| NTS | Nevada Test Site (DOE) |
| NTSB | National Transportation Safety Board |
| NV | Nevada Operations Office (DOE) |
| NVG | Night Vision Goggles (DOD) |
| NVOO | Nevada Operations Office |
| NWA | National Wilderness Area (DOI) |
| NWCC | National Water & Climate Center (USDA) |
| NWCG | National Wildfire Coordinating Group (USDA) |
| NWIS | National Water Information System (DOI) |
| NWLON | National Water-Level Observation Network (NOAA/NOS) |
| NWP | Numerical Weather Prediction |
| NWS | National Weather Service |
| NWSRFS | National Weather Service River Forecast Service (NOAA/NWS) |
| NWSTC | National Weather Service Training Center (NOAA/NWS) |
| NXDP | National Xeriscape Demonstration Program (DOI) |

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|---|---|
| O&C | Oregon and California Railroad Land Grants (DOI) |
| OAR | Office of Oceanic and Atmospheric Research (NOAA) |
| OASIS | Operational and Supportability Implementation System (FAA) |
| OB | Operational Build |
| OCAP | Operating Consortium of ASDAR Participants (WWP) |
| OCE | Office of the Chief Economist (USDA) |
| OCRWM | Office of Civilian Radioactive Waste Management |
| OCWWS | Office of Climate, Water, and Weather Services (NOAA/NWS) |
| OEH | Office of Emergancy Management |
| OFCM | Office of the Federal Coordinator for Meteorology |
| OGP | Office of Global Programs (NOAA) |
| OMB | Office of Management and Budget |
| OMEGA | Operational Medicine Environmental Grid Application (DOD) |
| OMPS | Ozone Mapping and Profiler Suite |
| ONR | Office of Naval Research |
| OOR | Object Oriented Redesign |
| OPAREA | Fleet Operational Area (DOD) |
| OPARS | Optimum Path Aircraft Routing System (DOD) |
| OPC | Operational Processing Centers |
| OPS-II | Operational Weather Squadron Production System, Phase II |
| OPUP | Open Principal User Processor |
| 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) |
| ORNL | Oak Ridge National Laboratory (DOE) |
| OROO | Oak Ridge Operations Office (DOE) |
| ORPG | Open Systems Radar Product Generator (NOAA/OAR) |
| ORR | Oak Ridge Reservation (DOE) |
| ORS | Optical Remote Sensing |
| OS | Office of Science, South Carolina |
| OS-21 | Observing System 21$^{st}$ Century (DOD) |
| OSC | On-Scene Commander (DOE) |
| OSDPD | Office of Satellite Data Processing and Distribution (NOAA/NESDIS) |
| OSE | Observing System Experiments (WWP) |
| OSEI | Operational Significant Event Imagery (NOAA/NESDIS) |
| OSHA | Occupational Safety and Health Administration |
| OSO | Office of Satellite Operations (NOAA/NESDIS) |
| OSSE | Observing System Simulation Experiments (WWP) |
| OSTEP | Ocean Systems Test and Evaluation Program (NOAA/NOS) |
| OSTP | Office of Science and Technology Policy |
| OTC | Operational Test Centers |
| OTH | Over the horizon (NOAA/OAR) |
| OTSR | Optimum Track Ship Routing (DOD) |
| OWF | Operational Weather Flight (DOD) |
| OWS | Operational Weather Squadron (DOD) |
| 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) |
| PAR | Phased Array Radar |
| PATMOS | Pathfinder Atmosphere (NOAA/NESDIS) |
| PAWRP | Phased Array Weather Radar Project |
| PBL | Planetary Boundary Layer (DOE) |
| PC | Program Council (OFCM) |

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|---|---|
| | Personal Computer (DOE) |
| PCB | Polychlorinated Biphenyl |
| PCMDI | Program for Climate Model Diagnosis and Intercomparison (DOE) |
| PD | Program Director (DOD) |
| PDD | Presidential Decision Directive |
| PDT | Product Development Team |
| PECAD | Production Estimates and Crop Assessment Division (USDA) |
| PIBAL | Pilot Balloon |
| PIPS | Polar Ice Prediction System (NOAA/NESDIS) |
| PIRATA | Pilot Research Moored Array in the Tropical Atlantic (NOAA/OAR) |
| PIREP | Pilot Report |
| PMC | Project Management Coordinator (DOE) |
| PMEL | Pacific Marine Environmental Laboratory (NOAA/ERL) |
| PNNL | Pacific Northwest National Laboratory (DOE) |
| PNT | Position, Navigation, and Timing (USCG) |
| POES | Polar-orbiting Operational Environmental Satellite (NOAA) |
| POP | Parallel Ocean Program (DOE) |
| POPS | Primary Oceanographic Prediction System (DOD) |
| PORTS | Physical Oceanographic Real-Time System (NOAA/NOS) |
| ppm | Part per Million (DOE) |
| PSDA | Post-Storm Data Acquisition (OFCM) |
| PSR | Polarimetric Scanning Radiometer (NOAA/OAR) |
| PSS | Plant Shift Superintendent |
| PUP | Principal User Processor |
| | |
| QPF | Quantitative Precipitation Forecast (NOAA/NCEP) |
| QuikSCAT | Quick Scatterometer |
| | |
| R&A | Research and Analysis |
| R&D | Research and Development |
| RAFC | Regional Area Forecast Center (WWP) |
| RAMS | Regional Atmospheric Modeling System (DOE) |
| RAMSDIS | RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (NOAA/NESDIS) |
| RAP | Radiological Assistance Program (DOE) |
| | Remedial Action Plan (DOE) |
| RARC | Regional Atmospheric Response Center (DOE) |
| RASS | Radio Acoustic Sounding System (NOAA/OAR and DOE) |
| RATS | Radio Automatic Theodolite System (NASA) |
| RAWS | Remote Automatic Weather Station (USDA/DOI) |
| RBCN | Regional Basic Climate Network (WWP) |
| RC | Reserve Component (DOD) |
| RCC | Regional Climate Center (NOAA/NESDIS) |
| RCTM | Road Condition and Treatment Module (FHWA) |
| RDA | Radar Data Acquisition |
| RDEC | Research Development and Engineering Center (DOD) |
| RDTE | Research, Development, Test and Evaluation (DOD) |
| REIP | Reengineered Enterprise Infrastructure Program (DOD) |
| RF | Radio Frequency |
| RFETS | Rocky Flats Environmental Technology Site (DOE) |
| RFO | Rocky Flats Office (DOE) |
| RFC | River Forecast Center (NOAA/NWS) |
| RMTN | Regional Meteorological Telecommunications Network (WWP) |
| ROC | Radar Operations Center (NOAA/NWS) |
| RPC | Rapid Prototype Center (NOAA/SEC) |
| RSA | Range Standardization and Automation (NASA) |
| RSAC | Transport and Dispersion Code at INEEL (DOE) |
| RSFWSU | Remote Sensing/Fire Weather Support Unit (DOI) |

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|---|---|
| RSL | Remote Sensing Laboratory |
| RSMC | Regional/Specialized Meteorological Centers (WWP) |
| RSS | Receiving Set Satellite (DOD) |
| RTH | Regional Telecommunications Hub (WWP) |
| RUC | Rapid Update Cycle (NOAA/OAR) |
| RVR | Runway Visual Range (FAA) |
| RWIS | Road Weather Information System (FHWA) |
| | |
| SAA | Satellite Active Archive |
| | Snow Accumulation Algorithm (DOI/BLM) |
| SAFETEA | Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003 (FHWA) |
| SALEX | Saharan Air Layer Experiment |
| SAMS | Stochastic Analysis, Modeling, and Simulation (DOI) |
| SAP | Special Access Program |
| SAR | Synthetic Aperture Radar (NOAA/NESDIS) |
| SARSAT | Search and Rescue Satellite Aided Tracking |
| SATCOM | Satellite Communications |
| SATS | Small Aircraft Transportation System (NASA) |
| SAWS | Stand Alone Weather Sensor (FAA) |
| SBIR | Small Business Innovation Research Program |
| SBUV | Solar Backscatter Ultra-violet Instrument (NOAA/NESDIS) |
| SCAN | Soil Climate Analysis Network (USDA) |
| SCAPA | Subcommittee for Consequence Assessment and Protective Actions |
| SCI | Sensitive Compartmented Information (DOD) |
| SDHS | Satellite Data Handling System (DOD) |
| SeaWiFS | Sea-viewing Wide Field Scanner (NASA) |
| SEC | Space Environment Center (NOAA/NCEP) |
| | Sun Earth Connection (NASA) |
| SEM | Space Environment Monitor (NOAA) |
| SEMSIM | Southeastern Michigan Snow and Ice Management (FHWA) |
| SEON | Solar Electro-optical Observing Network (DOD) |
| SESS | Space Environmental Sensor Suite |
| SFMR | Stepped Frequency Microwave Radiometer |
| SGP | Southern Great Plains (DOE) |
| SHEBA | Surface Heat Budget of the Arctic Ocean (DOE) |
| SHEP | State Highway Emergency Patrol (FHWA) |
| SHRP | Strategic Highway Research Program (FHWA) |
| SIGRID | Sea Ice in Gridded Format (NOAA/NESDIS) |
| SLF | Shuttle Landing Facility |
| SLRS-C | Spacelift Range System Contract (NASA) |
| SMC | Space and Missile Systems Center (DOD) |
| SMDC | Space and Missile Defense Command (DOE) |
| SMG | Spaceflight Meteorology Group (NASA) |
| SNDR | Subcommittee on Natural Disaster Reduction |
| SNL | Sandia National Laboratory (DOE) |
| SNODEP | SNOw DEPth |
| SNOTEL | Snow Pack Telemetry (USDA) |
| SOCC | Satellite Operations Control Center (NOAA/NESDIS) |
| SODAR | Sound Detection and Ranging (DOE) |
| SODAR/RASS | Sound Detection and Ranging/Radio Acoustic Sounding System (DOE) |
| SOF | Special Operations Forces (DOD) |
| SOLAS | International Convention for Safety of Life at Sea (NOAA/NCEP, DHS/USCG) |
| SOPA | Synchronous Orbit Plasma Analyzer (DOE) |
| SORD | Special Operations and Research Division (NOAA/ARL) |
| SPLASH | Hydrologic Code at LANL (DOE) |
| SPAWARSYSCOM | Space and Naval Warfare Systems Command |
| SPC | Storm Prediction Center (NOAA/NCEP) |
| SPO | System Program Office (DOD) |

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|---|---|
| SPP | Shared Processing Program |
| SQA | Software Quality Assurance |
| SR | Savannah River (DOE) |
| SRB | Solid Rocket Booster |
| SRNL | Savannah River National Laboratory (DOE) |
| SROO | Savannah River Operations Office |
| SRS | Savannah River Site |
| SRTC | Savannah River Technology Center (DOE) |
| SS&WSF | Snow Survey & Water Supply Forecasting (USDA) |
| SSIES | Special Sensor for Ions and Electrons (DOD) |
| SSJ | Special Sensor Precipitating Elecron and Ion Spectrometer (DOD) |
| SSM | Special Sensor Magnetometer (DOD) |
| SSM/I | Special Sensor Microwave/Imager (DOC, DOD, DOI) |
| SSM/T | Special Sensor Microwave/Temperature (DOD) |
| SSOB | Special Support Operations Branch (DOD) |
| SST | Sea Surface Temperature |
| SSU | Stratospheric Sounding Unit (NOAA) |
| SSUSI | Special Sensor Ultraviolet Spectrographic Imager (DOD) |
| STAR | Weather Data Format used at Pantex (DOE) |
| STIWG | Satellite Telemetry Interagency Working Group (OFCM) |
| STP | Solar-Terrestrial Physics |
| STS | Special Tactics Squadron (DOD) |
| STWDSR | Surface Transportation Weather Decision Support Requirements (FHWA) |
| SURFRAD | Surface Radiation Budget Station at NTS (DOE) |
| SVS | Synthetic Vision System (NASA) |
| SWA | Southwest Asia (DOD) |
| SWAFS | Space Weather Analysis and Forecasting System (DOD) |
| SWE | Snow Water Equivalent (DOI/BUREC) |
| SWO | Staff Weather Officer (DOD) |
| | Space Weather Operations (NOAA/OAR) |
| SWR | Supplemental Weather Radar (DOD) |
| SWSI | Surface Water Supply Index (USDA) |
| SXI | Solar X-Ray Imager (DOD) |
| | |
| T2 | Technology transfer |
| TAF | Terminal Aerodrome Forecast |
| TAL | Transatlantic Abort Landing (NASA) |
| TAMDAR | Troposphere Airborne Meteorological Data Reports (WWP) |
| TAO | Tropical Atmosphere Ocean |
| TAWS | Target Acquisition Weather Software (DOD) |
| TCP | Transformation Campaign Plan (DOD) |
| TDA | Tactical Decision Aid (DOD) |
| TDWR | Terminal Doppler Weather Radar (FAA) |
| TEA-21 | Transportation Equity Act for the 21st Century (FHWA) |
| TEC | Topographic Engineering Center (DOD) |
| | Total Electron Content (DOE) |
| TED | Total Energy Detector (NOAA/NESDIS) |
| TEDS | Tactical Environmental Data Server (DOD) |
| TESS | Tactical Environmental Support System (DOD) |
| THORPEX | The Observing System Research and Predictability Experiment (WWP) |
| TIMEX | Thunderstorm Initiation Mobile Experiment (NOAA/OAR) |
| TIROS | Television Infrared Observation Satellite (NOAA/NESDIS) |
| TOC | Tactical Operations Center (DOD) |
| TOE | Table of Organization and Equipment (DOD) |
| TOGA | Tropical Ocean and Global Atmosphere |
| TOVS | TIROS-N Operational Vertical Sounder (NOAA/NESDIS) |
| TNT | Trinitrotoluene (DOE) |

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|---|---|
| TPAWS | Turbulence Prediction and Warning System |
| TPC | Tropical Prediction Center (NOAA/NCEP) |
| TPW | Total Precipitable Water (NOAA/NESDIS) |
| TRACON | Terminal Radar Approach Control (FAA) |
| TRADOC | Training and Doctrine Command (DOD) |
| TRB | Transportation Research Board (FHWA) |
| TRITON | Triangle Trans-Ocean buoy Network (NOAA/OAR) |
| TRMM | Tropical Rainfall Measuring Mission (NASA) |
| TRU | Transuric (DOE) |
| TSIS | Total Solar Irradiance Sensor |
| TUAN | Tactical Unmanned Aerial Vehicle (DOD) |
| TWC | The Weather Channel |
| TWIP | Terminal Weather Information for Pilots (FAA) |
| TWP | Tropical Western Pacific (DOE) |
| TWR | Tactical Weather Radar (DOD) |
| | |
| UAV | Unmanned Aerial Vehicle (DOD) |
| UC | University of Chicago or California |
| UCAN | Unified Climate Access Network (USDA) |
| UCAR | University Corporation for Atmospheric Research |
| UHF | Ultra High Frequency |
| UK | United Kingdom |
| UN | United Nations |
| UNEP | United Nations Environment Program |
| UNESCO | United Nations Educational, Scientific and Cultural Organization (WWP) |
| UNLV | University of Nevada at Las Vegas (DOE) |
| UPOS | University Partnering for Operational Support (DOD) |
| USA | U.S. Army |
| USACE | U.S. Army Corps of Engineers |
| 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 |
| USAR | U.S. Army Reserve |
| USARAK | U.S. Army Alaska |
| USARC | U.S. Army Reserve Command |
| USAREUR | U.S. Army Europe |
| USARHAW | U.S. Army Hawaii |
| 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 |
| USFS | U.S. Forest Service |
| 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 |
| USSOCOM | U.S. Special Operations Command (DOD) |
| USWRP | U.S. Weather Research Program |
| UT | University of Tennessee |

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|---|---|
| UTC | Universal Time Coordinated (Zulu) |
| UV | Ultra-violet |
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| VA | Volcanic Ash |
| VAAC | Volcanic Ash Advisory Center (NOAA/NESDIS) |
| VAS | VISSR Atmospheric Sounder |
| VCP | Voluntary Cooperation Program (WWP) |
| VII | Vehicle Infrastructure Integration (FHWA) |
| VIIRS | Visible/Infrared Imager/Radiometer Suite |
| VIN | Vegetative Index Number (USDA) |
| VIRS | Visible and Infrared Scanner (NASA) |
| VISSR | Visible and Infrared Spin Scan Radiometer |
| VOC | Volatile organic compound |
| VISTAS | Visibility Improvement State and Tribal Association of the Southeast (DOI) |
| VORTEX | Verification of the Origins of Rotation in Tornadoes Experiment (NOAA/OAR) |
| VOS | Voluntary Observing Ship (WWP) |
| VPR | Vertical Profile of Reflectivity (DOI) |
| VSAT | Very Small Aperture Terminal (DOD) |
| VSL | Variable Speed Limit (FHWA) |
| VTMX | Vertical Transport and Mixing Experiment (DOE) |
| VTS | Vessel Traffic System (NOAA/NOS) |
| | |
| WAAS | Wide Area Augmentation System (FAA) |
| WAFC | World Area Forecast Center (WWP) |
| WAFS | World Area Forecast System (WWP) |
| WAMIS | World Agrometeorological Information Service (USDA) |
| 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) |
| WDA | Weather Data Analysis (DOD) |
| 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 |
| WG/VA | Working Group for Volcanic Ash (DOI) |
| WG/PSDA | Working Group for Post-Storm Data Acquisition (FEMA) |
| WGCV | Working Group on Calibration and Validation (NOAA/NESDIS) |
| WINCOM | Weather Information Communications (NASA) |
| WIMS | Weather Information Management System (USDA) |
| WIND | Weather Information and Display (DOE) |
| WIPP | Waste Isolation Pilot Plant (DOE) |
| WIS | WMO Information System(WWP) |
| 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 |
| WPDN | Wind Profile Demonstration Network (NOAA) |
| WPSM | Warfighter Physiological Status Monitoring (DOD) |
| WRD | Water Resources Division (DOI/USGS) |
| WRF | Weather Research and Forecast (DOC, DOD) |
| WRS | Weather Reconnaissance Squadron (DOD) |
| WRTC | Weather Readiness Training Center (DOD) |
| WSDDM | Weather Support to Deicing Decision Making (FAA) |

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|---|---|
| WSP | Weather Systems Processor (FAA) |
| WSR-88D | Weather Surveillance Radar-1988 Doppler (NEXRAD) |
| WSRC | Westinghouse Savannah River Company (DOE) |
| WSSRAP | Weldon Springs Site Remedial Action Project (DOE) |
| WST | Weather Specialty Team (DOD) |
| WTS | Washington TURU Solutions |
| WWCB | Weekly Weather and Crop Bulletin (USDA) |
| WWP | World Weather Program |
| WWW | World Weather Watch (WMO) |
| | World Wide Web |
| XOW | Air Force Director of Weather (DOD) |
| YMP | Yucca Mountain Project (DOE) |

# FEDERAL METEOROLOGICAL COORDINATING INFRASTRUCTURE

FEDERAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (FCMSSR)

FEDERAL COORDINATOR FOR METEOROLOGY

## INTERDEPARTMENTAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (ICMSSR)

### STANDING COMMITTEES

**ENVIRONMENTAL SERVICES, OPERATIONS AND RESEARCH NEEDS**

- Products and Services Innovations
  - ‣ Lightning Detection Systems
  - ‣ Research Results to Operations
  - ‣ 5D Environmental Data Cloud
  - ‣ Hydromet Assessment
  - ‣ Severe Local Storms Operations
  - ‣ Critical Skill Shortages
- Hurricane and Winter Storms Operations
- Natural Disaster Reduction / Post-Storm Data Acquisition
- Satellite Telemetry
- National Wildland Fire Weather
- Urban Meteorology
  - ‣ Joint Urban Test Beds
  - ‣ Joint Model Development and Evaluation

**INTEGRATED OBSERVING SYSTEMS**

- Atmospheric Observing Systems

**CLIMATE ANALYSIS, MONITORING AND SERVICES**

- ‣ Climate Services and Information Products

**COOPERATIVE RESEARCH**

- Tropical Cyclone Research
- Multifunction Phased Array Radar
- Weather Information for Surface Transportation
- ‣ Social Sciences Research
- ‣ Customer Decision Support Systems

**ENVIRONMENTAL INFORMATION SYSTEMS AND COMMUNICATIONS**

- Meteorological Codes
- Communications Interfaces and Data Exchange
- Frequency Management
- ‣ XML and Web Services

## PROGRAM COUNCILS

**NATIONAL SPACE WEATHER**

COMMITTEE FOR SPACE WEATHER

**NATIONAL AVIATION WEATHER**

COMMITTEE FOR AVIATION SERVICES AND RESEARCH

- Volcanic Ash

**NATIONAL OPERATIONAL PROCESSING CENTERS**

COMMITTEE FOR OPERATIONAL PROCESSING CENTERS

- Cooperative Support and Backup
  - ‣ Operational Community Modeling
  - ‣ Centralized Communications Management
  - ‣ Operational Data Acquisition for Assimilation

**MULTIFUNCTION PHASED ARRAY RADAR**

October 2008

LEGEND:
- • Designates a Working Group
- ‣ Designates a Joint Action Group
- Designates a Council or Group that is to be formed