The Federal Plan for Meteorological Services and Supporting Research

Fiscal Year 2011

OFCM
OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH

FCM-P1-2010

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

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FISCAL YEAR 2011

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PREFACE

Since 1965, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) has prepared an annual Federal Plan that articulates the provision of meteorological services and supporting research by agencies of the Federal government. The 2011 Federal Plan provides Congress and the Executive Branch with a comprehensive compilation of proposed programs for fiscal year (FY) 2011 and a review of agency programs from FY 2010. The Federal Plan's narratives, timelines, and schedules are current as of October 2010.

We have reorganized the Federal Plan this year to more clearly present a horizontal view of activities and plans across the Federal enterprise. Section 1 summarizes the resources appropriated by Congress for FY 2010 and the resources requested in the FY 2011 President's Budget. Please note that actual FY 2011 funding under continuing resolutions or eventual final appropriations bills are not described here. Section 2 contains narratives on operations and programs for providing meteorological services and supporting research and development, organized by service category rather than by department or agency as in preceding years. The service categories in Section 2 are the same as those used in Tables 1.4 and 1.5 of Section 1. This reorganization more closely follows the original intent when this annual plan was requested by Congress and the Executive Office of the President in 1963. Also new this year is an introductory segment for Section 2 that describes the Federal coordination and planning process. This segment replaces and expands on Appendix A found in recent past Federal Plans.

Reorganizing the Federal Plan to emphasize and clarify the horizontal integration that exists across departmental and agency structures is a work in progress. In subsequent years, we will continue to refine and improve this horizontal view of services, products, and supporting research by service category.

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

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH, FISCAL YEAR 2010

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AGENCY FUNDING FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The tables in this section summarize budgetary information of the Federal government for fiscal years 2010 and 2011. 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 2010 and are subject to later changes. The data for Fiscal Year (FY) 2011 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.

Table 1.1 contains fiscal information, by agency, for meteorological operations and supporting research. The table shows the funding level for FY 2010 based on Congressional appropriations, the budget request for FY 2011, the percent change, and the individual agencies' percent of the total Federal funding for FY 2010 and FY 2011.

DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 2011 is $92.4 million for operations and supporting research, up 21 percent from the FY 2010 funding level. An increase in funding for research and development programs more than offset a slight decrease in funding requested for meteorological operations. USDA has requested $75.9 million for research and development programs, a $16.2 million increase from 2010. Most of the funding increase is for the National Institute for Food and Agriculture (NIFA), representing increases in funding for weather and climate due to increases in the Hatch Act, McIntire-Stennis, Evans-Allen, and Animal Health formula programs, as well as other research projects. USDA funds research projects through NIFA 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. The Agricultural Research Service (ARS) is the USDA's chief scientific research agency. 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 environmental and economic sustainability of agricultural enterprises. Research at the USDA Forest Service includes studies of the long-term effects of air pollution on forests of the Sierra Nevada Ecosystem, Cascade and coastal forests in the Pacific Northwest, Rocky Mountains, Appalachian Mountains, and the northeastern U.S.

TABLE 1.1 METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH COSTS*, BY AGENCY

(Thousands of Dollars)

	Operations			% of FY2011	Supporting Research			% of FY2011	Total			% of FY2010	% of FY2011
AGENCY	FY2010	FY2011	%CHG	TOTAL	FY2010	FY2011	%CHG	TOTAL	FY2010	FY2011	%CHG	TOTAL	TOTAL
Agriculture	16665	16481	-1.1	0.4	59761	75924	27.0	3.2	76426	92405	20.9	1.5	1.5
Commerce/NOAA(Subtot)	2431392	3280712	34.9	82.3	137492	133904	-2.6	5.6	2568884	3414616	32.9	49.7	53.6
NWS	963880	1003193	4.1	25.2	36525	27000	-26.1	1.1	1000405	1030193	3.0	19.3	16.2
NESDIS	1398522	2209019	58.0	55.4	27970	28352	1.4	1.2	1426492	2237371	56.8	27.6	35.2
OAR	0	0	0	0	69997	75552	7.9	3.2	69997	75552	7.9	1.4	1.2
NOS	33078	29715	-10.2	0.7	0	0	0	0	33078	29715	-10.2	0.6	0.5
OMAO	35912	38785	8.0	1.0	3000	3000	0.0	0.1	38912	41785	7.4	0.8	0.7
Defense(Subtot)	272933	267926	-1.8	6.7	57606	54199	-5.9	2.3	330539	322125	-2.5	6.4	5.1
Air Force	180105	175381	-2.6	4.4	32744	32373	-1.1	1.4	212849	207754	-2.4	4.1	3.3
Navy	72307	73246	1.3	1.8	9926	10055	1.3	0.4	82233	83301	1.3	1.6	1.3
Army	20521	19299	-6.0	0.5	14936	11771	-21.2	0.5	35457	31070	-12.4	0.7	0.5
Homeland Security (Subtot)	24710	26430	7.0	0.7	0	0	0	0	24710	26430	7.0	0.5	0.4
USCG	24710	26430	7.0	0.7	0	0	0	0	24710	26430	7.0	0.5	0.4
Interior/BLM	4450	4105	-7.8	0.1	0	0	0	0	4450	4105	-7.8	0.1	0.1
Transportation(Subtot)	376664	384360	2.0	9.6	40680	39834	-2.1	1.7	417344	424194	1.6	8.1	6.7
FAA	376664	384360	2.0	9.6	36180	35334	-2.3	1.5	412844	419694	1.7	8.0	6.6
FHWA	0	0	0	0	4500	4500	0.0	0.2	4500	4500	0.0	0.1	0.1
EPA	0	0	0	0	9000	9000	0.0	0.4	9000	9000	0.0	0.2	0.1
NASA	7506	5979	-20.3	0.1	1730998	2065652	19.3	86.8	1738504	2071631	19.2	33.6	32.5
NRC	225	140	-37.8	0.0	275	175	-36.4	0.0	500	315	-37.0	0.0	0.0
DOE	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3134545	3986133	27.2	100.0	2035812	2378688	16.8	100.0	5170357	6364821	23.1	100.0	100.0
% of FY TOTAL	60.6%	62.6%			39.4%	37.4%			100.0%	100.0%			

*The FY 2010 funding reflects Congressionally appropriated funds; the FY 2011 funding reflects the amount requested in the President's FY 2011 budget submission to Congress.

The FY 2011 amount requested for meteorological operations is $16.5 million, down from $16.7 million in FY 2010. 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 World Agricultural Outlook Board (WAOB) operates the Joint Agricultural Weather Facility (JAWF), a global agricultural weather and information center located in Washington, D.C. JAWF agricultural meteorologists operationally monitor global weather conditions and assess 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. USDA is also actively involved in drought monitoring efforts in concert with the National Drought Mitigation Center.

DEPARTMENT OF COMMERCE (DOC)/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

National Weather Service (NWS)

The NWS funding request for the FY 2011 President's Budget totals $1,030,193,000 and 4649 full-time equivalent (FTE) employees. Requested increases in funding over the FY 2010 program include the following:

- ***Aviation Weather.*** NWS requests an increase of $15.136 million and 4 additional FTEs to fund the planned second year Next Generation Air Transportation System (NextGen) development activities for this multi-year, multi-agency effort to improve the Nation's air transportation system. The demand for air transportation is expected to more than double by 2025. The current National Airspace System (NAS) simply cannot accommodate the increased demand and will be saturated by 2015. The Joint Planning and Development Office (JPDO) developed a plan for accommodating the expected growth in demand. A critical component of the NextGen plan is a weather forecast process, with meteorologist intervention, that generates rapidly updated, high-resolution probabilistic weather information, consistent across space and time. This 4-Dimensional Weather Single Authoritative Source (4-D Weather SAS) will be stored in a Weather Information Database (WIDB) where it can be accessed by all NAS users. This funding increase supports the NOAA-led effort to develop a WIDB that will provide the aviation community an authoritative and timely source of weather information for decision support. This WIDB will integrate observed and forecast weather information and enable its use within an automated, multi-agency coordinated, air traffic management system. In its May 2008 report on the cost of flight delays to passengers, the airline industry and the economy, the Congressional Joint Economic Committee quantified the total cost of air traffic delays for 2007 at $41 billion. Federal Aviation Administration (FAA) records

indicate that on average, weather is a factor in 70 percent of these delays, or roughly $29 billion. The FAA estimates that two-thirds of these delays can be avoided with enhanced weather information fully integrated into its operational decision-making process, thus saving approximately $19 billion annually. This capability does not presently exist within the federal government, and the JPDO partner agencies are depending on NOAA, as the federal weather information experts, to deliver it.

- ***Space Weather.*** NWS requests an increase of $2 million to make required information technology (IT) security improvements to the Nation's National Critical Space Weather System required to maintain its authority to operate prior to the upcoming solar max. NOAA's Space Weather Program depends on the National Critical Space Weather System to: monitor the space environment and provide timely and accurate operational space weather forecasts, warnings, and alerts. The program is the sole civilian entity that (1) operates and maintains the US National Critical Space Weather System, (2) ingests and processes data from NOAA, NASA and other sources, (3) supports research to understand the processes that cause severe space weather, (4) transitions research into operations to improve services, and (4) archives data from NOAA and the Department of Defense (DOD) and makes it accessible to customers. Without the Authorization to Operate, all of the above activities will cease and the space weather products and services critical to our Nation's infrastructure and defense will be lost.
- ***Next-Generation Weather Radar (NEXRAD) Product Improvement (PI).*** NWS requests an increase of $3.150 million to fund projected costs associated with the fourth year of a five-year contract for the acquisition and deployment of dual-polarization technology to 122 NWS operational NEXRADs. Currently, NEXRAD only transmits and receives a horizontal signal. Dual polarization adds a vertical component. The addition of a vertical component greatly improves accuracy in estimation (quantity) and differentiation (rain, hail, snow, freezing rain, etc) of precipitation. The outcome will be an improvement in warnings to the public for flash flood warnings; improved identification of and warnings for tornados, severe hail, dangerous freezing rain, snow, and water management capability.
- ***Complete and Sustain NOAA Weather Radio (NWR).*** NWS requests an increase of $1.614 million to continue the modernization of the NOAA Weather Radio system via the Weather Radio Improvement Project (WRIP). The most critical component of WRIP is the replacement of the obsolete/unsupportable broadcast recoding equipment, the Console Replacement System (CRS), at each of the 122 Weather Forecast Offices (WFO). NWS will deploy the NWR Broadcast Management System (BMS) as a replacement for the CRS. The CRS is a main component of NOAA Weather Radio that converts text warning messages into digital voice which gives the NWS the ability to quickly disseminate Severe and High Impact Weather Warnings, Watches and forecasts and Non-Weather Emergency Messages to the public. This increase is required to keep the project on schedule for completion in FY 2012.
- ***Weather Forecast Office (WFO) Construction.*** NWS requests an increase of $3.150 million for modernization projects in the Alaska and Pacific Regions and replacement of end of life heating, ventilating, and air conditioning (HVAC) systems at six (6) WFOs with modern, high-efficiency (green) units. Specifically, increased funding completes Barrow, Alaska employee housing and the upper-air inflatable shelter, Weather Service

Office Koror renovations, and six HVAC replacements at WFOs with newer energy efficient models.

National Environmental Satellite, Data, and Information Services (NESDIS)

For FY 2011, NOAA/NESDIS requests an increase of $847,585,000 and four FTEs over the FY 2011 base program for a total of $2,209,019,000 and 835 FTEs. NESDIS is responsible for managing all aspects of remotely gathered environmental data. This includes procurement, launch, operation, product development, and product distribution of the Nation's civil operational environmental satellites and corresponding data. In addition, NESDIS manages the NOAA environmental data collections, provides assessments that describe climate, and disseminates data and information to meet the needs of users in commerce, industry, agriculture, science and engineering, as well as Federal, state, and local governments.

Modifications to major systems acquisition programs for FY 2011 include the following:

- ***Polar Orbiting Systems—Polar-orbiting Operational Environmental Satellite (POES).*** NESDIS requests a decrease of $2.261 million for a total of $40.874 million and 22 FTEs for the continuation of the POES (NOAA K-N') program, and continued support for the MetOp program. This is a planned decrease that was reflected in the FY 2010 President's Budget, resulting from the successful launch of the last POES satellite, NOAA-19, in February 2009.
- ***Polar Orbiting Systems—Joint Polar Satellite System (JPSS; formerly National Polar-orbiting Operational Environmental Satellite System (NPOESS).*** NESDIS requests an increase $678.6 million for a total of $1.0608 billion and 61 FTEs to continue development of instruments and acquire the spacecraft for the afternoon orbit under the restructured JPSS. The restructured JPSS will address NOAA's requirements to provide global environmental data such as cloud imagery, sea surface temperature, atmospheric profiles of temperature and moisture, atmospheric ozone concentrations, space weather observations, search and rescue, direct read-out, and data collection services. These data are used in numerical weather prediction models for near term (1-3 day) and mid-term (3-5 day) forecasts.
- ***Altimetry Mission—Jason-3.*** NESDIS requests an increase of $30 million for a total of $50 million to provide continuity of precise measurement of sea surface heights by continuing the development of the Jason-3 satellite in partnership with our European partners, which started in FY 2010.
- ***Geostationary Systems—Geostationary Operational Environmental Satellite (GOES) GOES-R Series.*** NESDIS requests an increase of $62.5 million for a total of $730 million and 46 FTEs to provide continued satellite engineering development and production activities for the instruments, satellite, and ground system development under contract in order to meet the planned launch readiness dates.
- ***Restoration of Climate Sensors.*** NESDIS requests new funding of $49.4 million to continue the development and acquisition of six NPOESS climate sensors that were de-manifested as a result of Nunn-McCurdy certification process. These critical sensors will continue to be developed for use on the JPSS and will address two climate-related

objectives within the context of the U.S. Climate Change Science Program. These objectives are (1) to fly critical climate sensors that had been planned for NPOESS, which represent the continuation of NASA's Earth Observing System (EOS) capabilities and (2) to fly those sensors that represent a fundamental contribution to NOAA's Climate Mission, which includes both heritage satellite and in situ observing systems.

- ***Constellation Observing System for Meteorology Ionosphere and Climate-2 (COSMIC-2).*** NESDIS requests $3.7 million to collaborate with the Taiwan National Space Organization (NSPO) for the launch of 12 satellites to provide replenishment and operational upgrade for the current COSMIC constellation.
- ***Deep Space Climate Observatory (DSCOVR)—Space Weather Observations.*** NESDIS requests $9.5 million and a total life-cycle cost of $85.1 million to initiate refurbishment of the DSCOVR satellite, formerly known as Triana, and the development of a Coronal Mass Imager to maintain continuity of solar wind data used for geomagnetic storm warnings.

Office of Oceanic and Atmospheric Research (OAR)

The requested FY 2011 funding for Weather and Air Quality Research (W&AQR) is $75.6 million—a net increase of $5.6 million or 0.8 percent from the FY 2010 appropriation. Increases of $14.7 million consist of funds to: partially cover inflationary cost increases within base programs ($1.0 million), fund the Water Resources Research to Operations Initiative ($7.7 million), and enhance the Multi-Function Phased Array Radar (MPAR) Program ($6.0 million). Proposed decreases of $8.5 million result from a reduction to the Unmanned Aircraft Systems Program(-$3.0 million) and from terminating unrequested funding added by Congress to W&AQR in FY 2010, including funds for: Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMAP) ($0.5 million); Redstone Unmanned Aircraft Systems (UAS) Development, AL ($0.3 million); National Weather Radar Test bed, OK ($2.0 million); Atmospheric Science Research (U. of TN) ($1.0 million), Boise Center Aerospace Laboratory (BCAL) Watershed Modeling, ID ($0.5 million); Southeastern Mercury Consortium, FL ($0.5 million); Aviation and Hurricane Research Utilizing UAS ($0.3 million); Observations, Modeling, and Visualizing Storm-Surge Inundation in Florida ($0.1 million); and New England Weather Technology and Research Initiative ($ 0.3 million).

National Ocean Service (NOS)

The $29 million provided through the FY 2011 budget will allow for continued operation of the National Water Level Observation Network (NWLON), the expansion of the Physical Oceanographic Real-Time System (PORTS®) program, further implementation of an advanced data quality control program known as the Continuous Operational Real-time Monitoring System (CORMS AI), and ongoing operation of the Ocean Systems Test and Evaluation Program (OSTEP), which is a development program for bringing new sensor technology into operations. 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.

Office of Marine and Aviation Operations (OMAO)

OMAO supports meteorological activities by collection of related data from ships and aircraft. The FY 2011 President's Budget request of $41,785,000, which represents a 7.4 percent increase over the FY 2010 appropriation, maintains OMAO's ship and aircraft support of meteorological data collection.

DEPARTMENT OF DEFENSE (DOD)

United States Air Force (USAF)/Air Force Weather Agency (AFWA)

USAF resources for meteorological support fall into four categories: general operations, investment and research, Defense Meteorological Satellite Program, and National Polar-orbiting Operational Environmental Satellite System (NPOESS) supporting research, development, test and evaluation efforts. The total Air Force Weather Agency (AFWA) weather operations and research funding for FY 11 is $207.7 million.

Operations

The operations support portion of AFWA's FY 11 budget is $175.4 million and funds day-to-day environmental support to the DOD, the Active and Reserve Components of the Air Force and Army, ten unified commands, and other agencies as directed by the Chief of Staff of the Air Force. Over 1,228 AFWA military and civilian personnel conduct these activities at more than 22 locations worldwide. Approximately 68 percent of personnel specialize in weather. The remainder includes communications, computer, administrative, and logistics specialists.

Supporting Research

The total AFWA budget for meteorological-related research during FY 11 is $32.4 million. As part of AF Smart Operations 21st Century, Air Force weather is investing in modernized environmental prediction technologies and global information grid technologies that enhance automation and save labor. In addition, Air Force weather is investing in the following efforts in FY 11 and beyond:

- ***Joint Environmental Toolkit (JET).*** Specifically, JET will eliminate redundancies and inefficiencies in current systems by extending, consolidating, and/or replacing the Operational Weather Squadron Production System, Phase II; the Joint Weather Impacts System; the New-Tactical Forecast System; and the weather effects decision aids portion of the Integrated Meteorological System (IMETS). Weather Research and Forecast (WRF) model. WRF advances, such as with the Land Information System (a collaborative effort with the National Aeronautics and Space Administration) 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.

- ***Modernizing space weather capabilities.*** Collaboration with U.S. and allied government and civilian agencies, along with ground-based sensing modernization, will result in a robust space-sensing capability.
- ***Cloud Depiction and Forecasting System (CDFS) II improvements.*** Improving CDFS techniques by doubling the resolution, integrating geosynchronous meteorological satellites 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).*** TDAs provide warfighters an automated way to "visualize" environmental impacts on operations. These tools continue to be integrated into AF and joint service command and control (C2) systems (e.g., mission planning systems) including Target Acquisition Weapons Software, Infrared Target Scene Simulation, and Tri-Service Integrated Weather Effects Decision Aid (T-IWEDA).
- ***Weather Data Analysis (WDA).*** 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.
- ***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 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 and in a manner that facilitates exploiting the current and forecasted weather conditions.

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 and 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 C4 Intelligence, Surveillance, and Reconnaissance data to meet operational and tactical mission planning and execution requirements.

United States Navy (USN)

The USN FY 2011 budget request for meteorological programs is $83.3 million, $73.2 million to support operations and $10.1 million to support enabling research.

Naval Oceanography Program (NOP)

The NOP remains a unique, world-class program. It focuses 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 decision makers by assessing the impact of atmospheric and ocean phenomena on platforms, sensors, and weapon systems. Additionally, Navy and Marine Corps 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 cost effective manner, providing a full spectrum of products and services to provide decision makers in the field with environmental decision superiority using 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 (CNO OPNAV N2/N6F5) sponsors programs in four closely related disciplines: meteorology, oceanography, geospatial information and services, and precise time and astrometry. All are used to protect ships, aircraft, fighting 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.

Battlespace On Demand (BonD). Naval Oceanography is about generating competitive advantage across the warfighting and shaping spectrum by linking forecasts to decisions. Our strategy, BonD, consists of overlapping tiers that build on the previous tiers to ultimately produce enhanced decision-making capabilities for the warfighter. The end result is decision superiority—making better decisions faster than the adversary.

- ***Tier 0.*** Data from various sources are collected, assimilated and fused to provide initial and boundary conditions that accurately describe the "as is" ocean and atmosphere environment, as well as the celestial and temporal reference frames.
- ***Tier 1.*** Data from satellites, altimetry, gliders, buoys and other collection methods are incorporated to initialize computations. Then, our high performance supercomputers run complex models to continually forecast and verify the future state of the ocean and atmosphere.
- ***Tier 2.*** The environment modeled in Tier 1 will impact sensors, weapons, platforms, and people, providing opportunities and restrictions for successful operations and warfighting. We define the influences on planning, force structure, targeting, timing, maneuver, tactics, techniques and procedures. The result is a "performance surface" that accounts for both the predicted environment and the capabilities and behaviors of the force – both allies and adversaries.
- ***Tier 3.*** Applications that run across the performance surface quantify risk at strategic, operational, and tactical levels. We provide actionable recommendations on force allocation and employment that directly enhance safety and warfighting effectiveness.

Littoral Battlespace Sensing, Fusion, and Integration (LBSF&I). LBSF&I is 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 facilitates 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 BonD framework, and supports the Battlespace Awareness Joint Capability Area through 2025.

Operational Support

Naval meteorological and oceanographic (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, Computers, and Intelligence and Space (C4I and Space) in San Diego, California.

Navy Integrated Tactical Environmental System (NITES). The Navy operates a distributed model in support of tactical weather prediction. Each NITES is a set of meteorology and oceanography forecast, database, and decision aid tools tailored for specific platforms and users. Five variants exist to support a variety of operators and platforms. Tactical environmental support system a DOD acquisition system category IV-T program refers collectively to all five variants of NITES. The Distributed Atmospheric Modeling Prediction System (DAMPS) allows users to ingest high-resolution data and on-scene observations into regional and global model information received from the Fleet Numerical Meteorology and Oceanography Center. The result is an on-scene weather model that provides accurate weather predictions for an operating area within a 24-hour timeframe.

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. The 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 Navy 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.

Research and Development (R&D)

Naval METOC R&D is 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. The *Cooperative Strategy for 21st Century Seapower* and the *Naval Operations Concept 2010* provides 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, MS, 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 resources, supports safe operations, and enhances dominance of the battlespace through superior understanding and exploitation of the environment. The Naval METOC community works 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.

United States Army (USA)

The U.S. Army has a requirement for $19.3 million for operational support and $11.8 million for research and development in FY 2011. Funding for operational support will decrease 6 percent while funding for research decreases 21 percent from FY 2010 to FY 2011. Staffing levels remain stable for FY 2011. Army monies for meteorology are spent on research and development related to the Army mission; the development, production, and maintenance of Army meteorological systems; and weather-related training at the Training and Doctrine Command (TRADOC) schools and centers.

Headquarters, Department of the Army, Deputy Chief of Staff, G-2, employs two full-time meteorologists for development of meteorology policy; coordination of meteorological support within the Department of the Army and with other DOD and Federal agencies and organizations; Department of the Army policy, concerning weather, environmental services, and oceanographic support to the Army (not to include 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 Air Force and the Army Staff.

The development and fielding of Army weather technologies are funded by the Program Manger (PM) Distributed Common Ground System-Army (DCGS-A). FY 2009 procurement funds (OPA) from DCGS-A were used for the integrated logistics support and sustainment of the Program of Record Integrated Meteorological System (IMETS) and new development for DCGS-A Weather Services. Northrop Grumman Technical Services (Tacoma/Lakewood, WA) and Physical Science Laboratory, New Mexico State University are the primary contractors supporting the OPA effort. OPA funding supports the testing and integration of weather capabilities such as the Air Force JET into DCGS-A. The IMETS Project Office transitioned to PM DCGS-A on 30 September 2007 to become DCGS-A Weather Services. Future funding for DCGS-A Weather Services will come from DCGS-A program office and Communications-Electronics Command Software Engineering Center (CECOM SEC). Until the systems are replaced by DCGS-A, maintenance and support for the fielded IMETS hardware will be transitioned to the DCGS-A Fort Hood Field Office. CECOM SEC provides the sustainment of IMETS software. DCGS-A weather services on both the Mobile Basic system and the V3.1 series of builds feature web applications and portal-based access to weather applications and products. An improved IWEDA on both versions of DCGS-A features a mission-oriented approach where multiple users contribute to building weather effects on selected sub-tasks, contributing to the overall mission. Rules for thousands of Army, Air Force, and Navy systems/sub-munitions and operations will be stored in a web-accessible centralized rules database at Fort Huachuca, AZ.

The Profiler program successfully executed a development and testing program, culminating in an Initial Operational Test and Evaluation 1QFY2005. Seventeen low-rate production (LRP) configuration systems were produced, including four System Design and Development models subsequently converted to an LRP configuration and 13 additional LRP systems. Full-rate production (FRP) was approved at a FRP Decision Review in FY 2005. The Profiler Block I system reached its Army Acquisition Objective of 108 systems with its FY 2008 contract award. Final production concluded with delivery of system number 108 in May 2010. As Block I

systems continue to be fielded in FY 2010, the development of next generation Profiler Block III system will begin. Profiler Block III is currently envisioned to be a hosted on a laptop computer, eliminating the need for dedicated vehicles and personnel, and potentially saving money for the Army in operations and support costs.

TRADOC transferred $109K in FY 2010 to the Air Combat Command for the maintenance and service of five Army automated surface observing sensor systems and two Army pole-mounted Tactical Meteorological Observing Systems at Fort Rucker, AL. Contract maintenance and service for these systems will be terminated by Air Combat Command in FY 2011 due to elimination of the contract vehicle per Resource Management Decision 802. Maintenance and service of Army-owned observing systems at Fort Rucker, AL, will become the sole responsibility of the Army in accordance with Army Regulation 115-10/Air Force Instruction 15-157, Weather Support for U.S. Army, 6 February 2010.

The Army Research Laboratory continued its research and development efforts in basic meteorology but will see a nearly $2.5 million reduction in funding from FY 2010 to FY 2011.

The Army Test and Evaluation Command's meteorology program budget will be substantially reduced in FY 2011. This is the same year the large computers used in the 4DWX system will reach the end of their life cycles. In anticipation, the budget alignment in FY 2010 shifted funds from instrumentation and program management funding lines to increase the amount provided to the 4DWX budget line. This shift provided funds for new computers, with a new system concept. Rather than running the 4DWX weather models at each range, the model execution for all the ranges will be accomplished at Dugway Proving Ground, using a very large computer with a backup computer at another range. The consolidated computer system began operations in September 2010. This approach saves funds in acquisition and maintenance, and provides more operational flexibility. The hardware, software, and system development costs for the consolidated system will be paid entirely with FY 2010 funds. The cost of the consolidated system is nearly as large as the budget reduction from FY 2010 to FY 2011; therefore, the instrumentation, program management, and other budget lines will remain nearly equivalent from FY 2010 to FY 2011.

DEPARTMENT OF HOMELAND SECURITY (DHS)

U.S. Coast Guard (USCG)

All of the USCG's funding for meteorological programs is for operations support. For FY 2011, the requested funding level is $26.4 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 THE INTERIOR (DOI)

Within the Bureau of Land Management (BLM), the Department of Interior (DOI) funds two principal programs—the soil, water, and air (SWA) program and the fire weather activities of the Office of Fire and Aviation (OFA). For FY 2011, funding for the SWA program is $1.143 million, down from $1.475 million in FY 2010. OFA funding for FY 2011 is $2.962 million and represents the DOI share of operations and the support of the Interagency Remote Automatic Weather Station (RAWS) network. An additional $1.2 million is recovered through reimbursable accounts with non-DOI participating agencies. Funded activities include maintenance, travel, transportation, services, supplies, equipment, and miscellaneous support costs. Some agencies also incur additional costs in support of this network through commercially contracted maintenance services.

The interagency RAWS network is an important tool for wildland fire management and directly supports the protection of life and property. All affected Federal agencies from within DOI participate in its acquisition, operation, and support. The BLM, in particular, has a unique role in the maintenance of the RAWS network, both through information technology (IT) data distribution services and technical equipment support. Participating agencies address common issues on a regular, interagency basis and coordinate efforts to ensure the collection of accurate and useful fire weather data.

DEPARTMENT OF TRANSPORTATION (DOT)

Federal Aviation Administration (FAA)

For 2011, FAA requested a total of $402.0 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 2010 was $391.0 million. For FY 2011, FAA requested an additional $11.2 million, representing a 2.8 percent increase in total funding.

The changes include a $1.4 million increase to $105.8 million for systems acquisition costs for new and increased programs for NextGen (see below); an increase in operations support from $285.5 million to $295.3 million; and an increase $1.5 million to $36.5 million for aviation weather research (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 and to the dissemination of weather products, graphics, and decision-making information to 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, summer and winter storm activity, etc. Additional work is being done to improve models and to develop advanced weather radar techniques.

Federal Highway Administration (FHWA)

The total FHWA request for surface transportation weather programs in FY 2011 is $4.5 million, all of which will be used for supporting research and special programs.

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 (DOT), 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* has developed, demonstrated, and supported the deployment of a nationwide surface transportation weather observing and forecasting system, and is fostering nationwide data-sharing capabilities. The *Clarus* System allows 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 multiyear effort was 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 promote deployment by the private sector, and provide assistance to public agencies in procuring the MDSS services from the private sector. Over the past four years multiple benefit/cost analyses have been conducted, all of which document that the benefits of deploying MDSS always outweigh the costs, sometimes quite significantly.

In 2006, the FHWA completed a study on how Traffic Management Centers (TMC) 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. Investigators found very limited integration and application of weather information for TMC operations. To advance the state of the practice, the Road Weather Management Program initiated a project to develop a self-assessment guide (http://ntl.bts.gov/lib/30000/30400/30471/14437.pdf) to help TMCs evaluate their weather information integration needs and assist them in creating a plan to meet those needs. The guide is currently being promoted and deployed around the country. 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 ongoing and future projects were shaped by three critical program development activities. In 2002, the FHWA asked the National Research Council (NRC) Board of Atmospheric Sciences and 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 roadways. 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.

Then, 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.

In 2010, the AMS, with the support of FHWA, conducted a second Road Weather Policy Forum. The forum provided an opportunity to assess what has been accomplished since the first forum, as well as to shape future investments. While much had been accomplished, it was recognized that much more needed to be done. The results of the forum were captured in a summary report, identifying three primary areas in need of study: documenting the wide range of transportation users' needs, better monitoring of weather and road conditions through fixed and mobile

observation networks, and further developing such science challenges as boundary layer modeling and integrated decision support systems.

These three activities have been instrumental in shaping FHWA's program plan and will continue to support the agency's investment decisions. In addition, they have helped strengthen the working relationship between the FHWA and NOAA. In July 2005, the two agencies signed a memorandum of understanding (MOU), which has enabled the two agencies to work together to achieve shared goals for a safer and more efficient surface transportation system. In November 2010, a second MOU was signed, which extended this collaboration. By working together, these two agencies are able to take advantage of each other's investments and expertise, as well as promote improved surface transportation weather training, products, and services.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of the EPA's funding of meteorological and air quality programs is for supporting basic and applied research. The anticipated funding level in FY 2011 for directed meteorological research is about $9 million.

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 human health and sensitive 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 2011 as in FY 2010.

EPA's Research Grants 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 2011 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $9 million listed above for directed meteorological research.

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 global-to-regional-to-urban-local formation and transport of air contaminants in support of the revisions to the National Ambient Air Quality Standards and ecosystem protection strategies. 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)

In FY 2010, NASA spent a total of $1.739 billion on meteorological operations ($7.506 million) and supporting research ($1.731 billion). NASA supports meteorological 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 launch and landing operations.

The SMD objective in weather and climate research is to improve accuracy of severe weather forecasts and global climate predictions through understanding of the atmosphere, land and oceans, including ecosystems, and their mutual interactions. The greatest challenge is to observe the continuum of weather-to-climate processes and produce models of future conditions 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.

For FY 2011, a 19 percent increase in NASA's research budget request to $2.066 billion funds a Climate Change Initiative that will greatly accelerate NASA's formulation, development, and launch of all fifteen Decadal Survey missions assigned to NASA; all Decadal Survey missions are relevant to research on global and regional climate change. The budget increase also recognizes and supports the need for continuity in critical climate observations and data records.

NUCLEAR REGULATORY COMMISSION (NRC)

For FY 2011, the NRC's total planned expenditure of $315,000 ($140,000 for operations and $175,000 for supporting research) is for meteorological operations to continue technical assistance for the analysis of atmospheric dispersion for routine and postulated accidental releases from nuclear facilities; for conducting meteorological research in support of licensing activities; 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 into 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. Current research activities include quantifying the storm surge from severe weather events and updating the hydrometeorological reports (HMRs) and methods used to estimate the effects of extreme precipitation events. This

work is prioritized for those areas of the United States where new nuclear power plants are proposed and will provide the design basis for flood protection systems.

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 1.2 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." In FY 2011, total Operational Costs requested are $3.99 billion with a total of $1.70 billion for Operations Support, $2.67 billion for Systems Acquisition, and $19.5 million for Special Programs.

Table 1.3 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 2011, agencies will obligate a total of $2.38 billion in supporting research funds in the following manner: $1.30 billion to research and development and $1.08 billion to systems development.

AGENCY FUNDING BY SERVICE CATEGORY

Tables 1.4 and 1.5 summarize how the agencies plan to obligate FY 2011 funds for meteorological services and supporting research, respectively, by service category. Table 1.4 details the distribution of FY 2011 operational funds with basic services receiving 77.9 percent, aviation 10.3 percent, surface transportation 2.2 percent; agricultural and land management 0.3 percent, military 6.4 percent, wildland fire weather 0.2 percent, climate 0.6 percent, space weather 0.6 percent, emergency response and homeland security 0.7 percent, hydrometeorology and water resources 0.3 percent, and other specialized services 0.5 percent.

Table 1.5 shows the distribution of supporting research funds among the service categories with basic services receiving 5.2 percent, aviation 2.0 percent, surface transportation, 0.2 percent; agricultural and land management 2.9 percent, military 2.1 percent, wildland fire weather 0.2 percent, climate 60.2 percent, space weather 26.8 percent, emergency response and homeland security 0.0 percent, hydrometeorology and water resources 0.0 percent, and other specialized services 0.4 percent. The service category definitions are described below:

TABLE 1.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Operations Support FY2010	Operations Support FY2011	Systems Acquisition FY2010	Systems Acquisition FY2011	Special Programs FY2010	Special Programs FY2011	Total FY2010	Total FY2011	Total %CHG	% of FY2010 TOTAL
Agriculture	15600	15462	635	587	430	432	16665	16481	-1.1	0.4
Commerce/NOAA(Subtot)	1124245	1150947.4	1292531.6	2116377	14615	13388	2431392	3280712	34.9	82.3
NWS	867222	902462	93154	97581	3504	3150	963880	1003193	4.1	25.2
NESDIS	199165	190223	1199357	2018796	0	0	1398522	2209019	58.0	55.4
OAR	0	0	0	0	0	0	0	0	0	0
NOS	33078	29715	0	0	0	0	33078	29715	-10.2	0.7
OMAO	24780	28547	21	0	11111	10238	35912	38785	8.0	1.0
Defense(Subtot)	224698	221033	48000	46658	235	235	272933	267926	-1.8	6.7
Air Force	141158	137638	38947	37743	0	0	180105	175381	-2.6	4.4
Navy	70862	71782	1445	1464	0	0	72307	73246	1.3	1.8
Army	12678	11613	7608	7451	235	235	20521	19299	-6.0	0.5
Homeland Security (Subtot)	24710	26430	0	0	0	0	24710	26430	7.0	0.7
USCG	24710	26430	0	0	0	0	24710	26430	7.0	0.7
Interior/BLM	993	993	332	0	3125	3112	4450	4105	-7.8	0.1
Transportation(Subtot)	288353	279280	85947	102716	2364	2364	376664	384360	2.0	9.6
FAA	288353	279280	85947	102716	2364	2364	376664	384360	2.0	9.6
FHWA	0	0	0	0	0	0	0	0	0	0
EPA	0	0	0	0	0	0	0	0	0	0
NASA	7506	5979	0	0	0	0	7506	5979	-20.3	0.1
NRC	225	140	0	0	0	0	225	140	-37.8	0.0
DOE	0	0	0	0	0	0	0	0	0	0
TOTAL	1686330	1700264	1427446	2266338	20769	19531	3134545	3986133	27.2	100.0
% of FY TOTAL	53.8%	42.7%	45.5%	56.9%	0.7%	0.5%	100.0%	100.0%		

TABLE 1.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Research & Development		Systems Development		Special Programs		Total			% of FY2010
	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	%CHG	TOTAL
Agriculture	59761	75924					59761	75924	27.0	3.2
Commerce/NOAA(Subtot)	127622	128359	9870	5545	0	0	137492	133904	-2.6	5.6
NWS	29525	24325	7000	2675	0	0	36525	27000	-26.1	1.1
NESDIS	27970	28352	0	0	0	0	27970	28352	1.4	1.2
OAR	68127	73682	1870	1870	0	0	69997	75552	7.9	3.2
NOS	0	0	0	0	0	0	0	0	0	0
OMAO	2000	2000	1000	1000	0	0	3000	3000	0.0	0.1
Defense(Subtot)	33461	31554	24145	22645	0	0	57606	54199	-5.9	2.3
Air Force	8599	9728	24145	22645	0	0	32744	32373	-1.1	1.4
Navy	9926	10055	0	0	0	0	9926	10055	1.3	0.4
Army	14936	11771	0	0	0	0	14936	11771	-21.2	0.5
Homeland Security (Subtot)	0	0	0	0	0	0	0	0	0	0
USCG	0	0	0	0	0	0	0	0	0	0
Interior/BLM	0	0	0	0	0	0	0	0	0	0
Transportation(Subtot)	40680	39834	0	0	0	0	40680	39834	-2.1	1.7
FAA	36180	35334	0	0	0	0	36180	35334	-2.3	1.5
FHWA	4500	4500	0	0	0	0	4500	4500	0.0	0.2
EPA	9000	9000	0	0	0	0	9000	9000	0.0	0.4
NASA	847683	1011549	883315	1054103	0	0	1730998	2065652	19.3	86.8
NRC	275	175	0	0	0	0	275	175	-36.4	0.0
DOE	0	0	0	0	0	0	0	0	0	0
TOTAL	1118482	1296395	917330	1082293	0	0	2035812	2378688	16.8	100.0
% of FY TOTAL	54.9%	54.5%	45.1%	45.5%	0	0	100.0%	100.0%		

TABLE 1.4 AGENCY OPERATIONAL COSTS, BY SERVICE CATEGORIES

(Thousands of Dollars)

AGENCY	Basic Meteorology		Aviation		WIST		Agriculture & Land Management		General Military		Wildland Fire		Climate		Space Weather		Homeland Security		Hydrometeorology		Other		Total	
	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011
Agriculture	231	0	0	0	0	0	12551	12597	0	0	3883	3884	0	0	0	0	0	0	0	0	0	0	16665	16481
Commerce/NOAA(Subtot)	2258540	3103323	23499	26676	87919	86201	0	0	0	0	1433	1433	22535	24813	11014	13014	1298	1333	10518	10531	14636	13388	2431392	3280712
NWS	843,399	876,082	23,499	26,676	54,841	56,486	0	0	0	0	1,433	1,433	16,153	16,315	11,014	13,014	0	0	10,037	10,037	3,504	3,150	963880	1003193
NESDIS	1,398,522	2,209,019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1398522	2209019
OAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOS	0	0	0	0	33078	29715	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33078	29715
OMAO	16619	18222	0	0	0	0	0	0	0	0	0	0	6382	8498	0	0	1298	1333	481	494	11132	10238	35912	38785
Defense(Subtot)	0	0	0	0	0	0	0	0	258499	255909	0	0	0	0	14434	12017	0	0	0	0	0	0	272933	267926
Air Force	0	0	0	0	0	0	0	0	165671	163364	0	0	0	0	14434	12017	0	0	0	0	0	0	180105	175381
Navy	0	0	0	0	0	0	0	0	72307	73246	0	0	0	0	0	0	0	0	0	0	0	0	72307	73246
Army	0	0	0	0	0	0	0	0	20521	19299	0	0	0	0	0	0	0	0	0	0	0	0	20521	19299
Homeland Security (Subtot)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24710	26430	0	0	0	0	24710	26430
USCG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24710	26430	0	0	0	0	24710	26430
Interior/BLM	0	0	0	0	0	0	1475	1143	0	0	2975	2962	0	0	0	0	0	0	0	0	0	0	4450	4105
Transportation(Subtot)	0	0	376664	384360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	376664	384360
FAA	0	0	376664	384360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	376664	384360
FHWA	0	0	0	0	0	0	0	0	0	0	0	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	0	0	0	0	0	0	0	0	0	0
NASA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7506	5979	7506	5979
NRC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	225	140	0	0	0	0	225	140
DOE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2258771	3103323	400163	411036	87919	86201	14026	13740	258499	255909	8291	8279	22535	24813	25448	25031	26233	27903	10518	10531	22142	19367	3134545	3986133
% of FY TOTAL	72.1%	77.9%	12.8%	10.3%	2.8%	2.2%	0.4%	0.3%	8.2%	6.4%	0.3%	0.2%	0.7%	0.6%	0.8%	0.6%	0.8%	0.7%	0.3%	0.3%	0.7%	0.5%	100.0%	100.0%

TABLE 1.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE CATEGORIES

(Thousands of Dollars)

AGENCY	Basic Meteorology		Aviation		WIST		Agriculture & Land Management		General Military		Wildland Fire		Climate		Space Weather		Homeland Security		Hydrometeorology		Other		Total	
	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011	FY2010	FY2011
Agriculture	2595	2595	0	0	0	0	51877	68040	0	0	5289	5289	0	0	0	0	0	0	0	0	0	0	59761	75924
Commerce/NOAA(Subtot)	134767	120929	2125	12375	0	0	0	0	0	0	600	600	0	0	0	0	0	0	0	0	0	0	137492	133904
NWS	35,425	15,650	500	10,750	0	0	0	0	0	0	600	600	0	0	0	0	0	0	0	0	0	0	36525	27000
NESDIS	27,970	28,352	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27970	28352
OAR	68372	73927	1625	1625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69997	75552
NOS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OMAO	3000	3000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3000	3000
Defense(Subtot)	0	0	0	0	0	0	0	0	54027	50242	0	0	0	0	3579	3957	0	0	0	0	0	0	57606	54199
Air Force	0	0	0	0	0	0	0	0	29165	28416	0	0	0	0	3579	3957	0	0	0	0	0	0	32744	32373
Navy	0	0	0	0	0	0	0	0	9926	10055	0	0	0	0	0	0	0	0	0	0	0	0	9926	10055
Army	0	0	0	0	0	0	0	0	14936	11771	0	0	0	0	0	0	0	0	0	0	0	0	14936	11771
Homeland Security (Subtot)	0	0	0	0	0	0	0	0	0	0	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	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	0	0	0	0	0	0	0	0	0	0
Transportation(Subtot)	0	0	36180	35334	4500	4500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40680	39834
FAA	0	0	36180	35334	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36180	35334
FHWA	0	0	0	0	4500	4500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4500	4500
EPA	0	0	0	0	0	0	0	0	0	0	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	0	0	1123000	1431000	607998	634652	0	0	0	0	0	0	1730998	2065652
NRC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	275	175	0	0	0	0	275	175
DOE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	137362	123524	38305	47709	4500	4500	51877	68040	54027	50242	5889	5889	1123000	1431000	611577	638609	275	175	0	0	9000	9000	2035812	2378688
% of FY TOTAL	6.7%	5.2%	1.9%	2.0%	0.2%	0.2%	2.5%	2.9%	2.7%	2.1%	0.3%	0.2%	55.2%	60.2%	30.0%	26.8%	0.0%	0.0%	0	0	0.4%	0.4%	100.0%	100.0%

- ***Basic Services.*** Basic services include the basic meteorological service system, to include observations, public weather forecasts, severe weather warnings and advisories, and the meteorological satellite activities of NOAA. Basic services also include the operations and supporting research of other Federal agencies that have been identified as contributing to basic meteorological services.
- ***Aviation Services.*** Aviation services are those specialized meteorological services and facilities established to meet the requirements of general, commercial, and military aviation. Civil programs that are directly related to services solely for aviation and military programs in support of land-based aviation and medium- or long-range missile operations are included. Detailed aviation services/products for specific areas include, but are not limited to, ceiling and visibility, convective hazards, en route winds and temperatures, ground de-icing, in-flight icing, terminal winds and temperatures, turbulence, volcanic ash, and other airborne hazardous materials.
- ***Surface Transportation.*** Surface transportation services are those specialized meteorological services and facilities established to meet the weather information needs of the following surface transportation sectors: roadways, long-haul railways, the marine transportation system, rural and urban transit, pipeline systems, and airport ground operations. The roadway sector includes state and Federal highways and all state and local roads and streets. The marine transportation system includes coastal and inland waterways, ports and harbors, and the intermodal terminals serving them. Rural and urban transit includes bus and van service on roadways and rail lines for metropolitan subway and surface “light-rail” systems.
- ***Agriculture and Land Management Meteorological Services.*** Agricultural and land management meteorological services are 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 land areas. Meteorological services specifically tailored for wildland fire management are reported under the wildland fire weather service category.
- ***Military Services.*** Military services are those meteorological operations, services, and capabilities established to meet the unique requirements of military user commands and their component elements. Programs and services that are not uniquely military in nature are reported under another service category (e.g., Basic Services, Aviation Services [civilian], Surface transportation Services, or Emergency Response and Homeland Security Services).
- ***Wildland Fire Weather Services.*** Wildland fire weather services are those specialized meteorological services and facilities established to meet the requirements of the wildfire management community at the Federal, state, tribal, and local levels. The primary areas of service are to support the reduction of wildfire initiation potential and the mitigation of both human and environmental impacts once initiation does occur. Services can include support to first responders and land managers and climate services tailored to wildland fire management.
- ***Climate Services.*** Climate services are those specialized meteorological services and facilities established to meet the requirements of Federal, state, and local agencies for

information about trends in seasonal, interseasonal, or longer aspects of the atmosphere-hydrosphere-land surface system. Climate services include information on both oscillatory patterns (cycles varying over periods of several years to several decades) and longer-term secular trends in climate.

- ***Space Weather Services.*** Space weather services are those specialized meteorological services and facilities established to meet the needs of users for information on extreme space weather events, also known as solar storms, which can affect terrestrial systems, the Earth's atmosphere, and the near-Earth space environment. Space weather services include monitoring and reporting of solar storms and their effects on the Earth's atmosphere and geomagnetic fields. Early warning of an approaching solar storm, so that timely protective response is possible, is an important part of space weather services.
- ***Emergency Response and Homeland Security Services.*** Emergency response and homeland security services are those specialized meteorological services and facilities established to meet the requirements of Federal, state, and local agencies responding to natural disasters and security incidents. This category includes the use of atmospheric transport and diffusion (ATD) models for predicting the dispersion of airborne toxic substances; it also includes natural disaster monitoring and prediction services and the transport of water-borne toxic substances not included in basic services.
- ***Hydrometeorology and Water Resources Services.*** Hydrometeorology and water resources services are those specialized meteorological services and facilities that combine atmospheric science, hydrology, and water resources in order to meet the requirements of Federal, state, and local agencies for information on the effects of precipitation events on infrastructure, water supplies, and waterways. These products and services also meet the needs of the general public in the conduct of everyday activities and for the protection of lives and property.
- ***Other Specialized Services.*** Other specialized services include weather and climate information services and facilities established to meet the special needs of user agencies or constituencies not included in basic services or the preceding service categories. This service category includes any efforts to integrate the social sciences into meteorological operations, applications, and services not already described in the preceding sections.

PERSONNEL ENGAGED IN METEOROGICAL OPERATIONS

Table 1.6 depicts agency staff resources engaged in meteorological operations. The total agency staff resources requested for FY 2011 is 8,898. This total represents a modest 1.4 percent increase from FY 2010.

TABLE 1.6 PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

(Units are Full time Equivalent Staff Years)

AGENCY	FY 2010	FY 2011	%CHG	% of FY 2011 TOTAL
Agriculture	135	132	-2.2	1.5
Commerce/NOAA (sub-total)	5547	5569	0.4	62.6
NWS	4645	4649	0.1	52.2
NESDIS (sub-total)	682	682	0.0	7.7
NESDIS	682	682	0.0	7.7
Reimbursed	0	0	0	0
OAR	0	0	0	0
NOS	114	119	4.4	1.3
OMAO	106	119	12.0	1.3
Defense(Subtotal)	2028	2124	4.7	23.9
Air Force	1133	1228	8.4	13.8
Navy	415	415	0.0	4.7
Marine Corps	369	370	0.3	4.2
Army	111	111	0.0	1.2
Homeland Security-USCG	108	108	0.0	1.2
Interior/BLM(Subtotal)	38	36	-5.3	0.4
BLM Soil/Water/Air Program	6	6	0.0	0.1
BLM Fire Weather Program	32	30	-6.3	0.3
Transportation(Subtotal)	875	893	2.1	10.0
FHWA	4	4	0.0	0.0
FAA	871	889	2.1	10.0
EPA	0	0	0	0
NASA	41	34	-17.5	0.4
NRC	2	2	0.0	0.0
DOE	0	0	0	0
TOTAL	8774	8898	1.4	100.0

INTERAGENCY FUND TRANSFERS

Table 1.7 summarizes the reimbursement of funds from one agency to another during FY 2010. 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 ear-to-year, the pattern shown is essentially stable and reflects a significant level of interagency cooperation.

TABLE 1.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

		FY 2010 Funds ($K) Estimated or Planned		
Agency Funds Transferred from:	Agency Funds Transferred to:	Operations	Supporting Research	
USDA/USFS	DOI/BLM	620		RAWS maintenance
		101		Lightning contract
Air Force	NOAA			
Air Force Weather	DOC/NOAA/NWS	2706	120	NEXRAD
Air Force Weather	DOC/NOAA/NWS	50		ASOS
Air Force Weather	OFCM	150		OFCM cost share
Air Force Weather	OFCM	30		Aircraft data
Air Force Weather	USGS (Dept of Interior)	525		Magnetometer
Air Force Weather	NASA		837	Land Info System
Air Force Weather	NASA	366		JPL tech data
Air Force Weather	NSF/UCAR/NCAR		2056	WRF
Air Force Weather	NSF/UCAR/NCAR		1220	Data Assimilation
Air Force Weather	NSF/UCAR/NCAR	250		Ensembles
Air Force Weather	GSA	117		Data admin
Air Force Weather	NOAA	155		Shared Processing Program
Corps of Engineers	National Weather Service	553		
Corps of Engineers	US Geological Survey	17265		
TRADOC	Air Combat Command	109		
FAA(Contract Weather)	NWS APAIDS in Alaska	128		
FAA(Contract Weather)	NWS Cascade Locks	13		
FAA(NEXRAD)	NWS	2711		
FAA(ASOS)	NWS	7423		
NASA	DOD/USAF/45th SW	1780		
	DOD/USAF/Edwards AFB	110		
	DOC/NOAA/NDBC	103		
	DOC/NOAA/SMG	1800		
DOI/BLM SWA	USDA-NRCS	222		
DOI/BLM OFA	NOAA	10		

FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

Table 1.8 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 any longer.

TABLE 1.8 FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

TYPE OF OBSERVATION by AGENCY	No. of 2010 Locations
Surface, land	
Commerce (all types)	841
Air Force (U.S. & Overseas)	265
Navy (U.S. & Overseas)	68
Marine Corps (U.S. & Overseas)	13
Army (U.S. & Overseas)	67
Transportation (FAA Contract Wx Obsg Stn)*	148
Transportation (FAA Auto Wx Obsg Stn - AWOS)	180
Transportation (FAA Auto Wx Sensor Sys - AWSS)	44
Transportation (FAA Auto Sfc Obsg Sys - ASOS)**	571
Transportation (FHWA-Road Wx Obsg Stn)	2127
Homeland Security (USCG Coastal)	50
Interior (BLM Soil/Water/Air Program)	250
Interior (BLM Office of Fire and Aviation)	971
Agriculture	979
Agriculture (NRCS active manual snow courses)	950
Agriculture (NRCS automated SNOTEL stations)	790
NASA (all types)	46
Total	8360
*Note: All 148 FAA Contract Wx Obsg Stations are colocated with a FAA or Commerce (NWS) ASOS	
**Note: Transportation (FAA oversight Auto Sfc Obsg Sys, non-Fed inspected) 1200	
Surface, marine	
Commerce (SEAS-equipped ships)	622
Commerce (Coastal-Marine Autom Network)	56
Commerce (NOS/PORTS - only stations with met sensors)	61
Commerce (Buoys--moored)	98
Commerce (Buoys--drifting)	21
Commerce (NOS/NWLON - only stations with met sensors)	176
Navy (Ships with met personnel)	29
Navy (Ships without met personnel)	255
Homeland Security (USCG Cutters)	250
NASA (Buoys - moored)	2
Total	1570

TABLE 1.8 FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

TYPE OF OBSERVATION by AGENCY		No. of 2010 Locations
Upper air, balloon		
Commerce (U.S.)		102
Commerce (Foreign, Cooperative)		22
Air Force, Mobile		29
Army, Fixed (U.S. & Overseas)		12
Army, Mobile (U.S. and Overseas)		13
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
	Total	231
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
	Total	28
Doppler weather radar (WSR-88D) sites		
Commerce (NWS)		121
Air Force (U.S. & Overseas)		26
Transportation (Off CONUS)		12
	Sub-total	159
Doppler weather radar (Not WSR-88D) sites		
Air Force (Fixed)		11
Army		6
Navy (Fixed)		9
	Sub-total	26
Airport Terminal Doppler weather radars		
Transportation (Commissioned)		45
	Sub-total	45
Conventional radar (non-Doppler) sites		
Commerce (NWS)		2
Air Force, Mobile Units		35
Army (U.S. and Overseas)		3
Transportation (FAA (WSP))		34
	Sub-total	74
		304

TABLE 1.8 FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

TYPE OF OBSERVATION by AGENCY		No. of 2010 Locations
Off-site WSR-88D Principle User Processors (PUPs)		
Air Force (OPUPs only)		99
Marine Corps (U.S. & Overseas)		9
Army		2
NASA (Kennedy Space Center (KSC) Applied Meteorology Unit)		1
	Total	111
Weather reconnaissance Aircraft		
Commerce (OMAO)		3
Air Force Reserve Command (AFRC) - WC-130J		10
	Total	13
Geostationary meteorological satellites (No. operating)		
Commerce (2 primary, 1 standby, 1 servicing South America)		5
Polar meteorological satellites (No. operating)		
Commerce (2 primary - one US; one European, 3 standby)		6
Air Force (2 primary, 3 standby)		5
Navy (WINDSAT and GFO)		1
	Total	12
Electric Field Mills (Surface)		
NASA (KSC)		31
	Total	31
Lightning Detection Systems		
Air Force (ER&WR - Cloud - Ground)		2
Air Force (ER&WR - NLDN)		2
Army		2
NASA KSC (4D Total Lightning)		1
	Total	7

SECTION 2

FEDERAL METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH PROGRAMS

FEDERAL COORDINATION AND PLANNING FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

The mission of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (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. Its high-level focus includes cross-agency needs and requirements, issues and problems, studies, reports, plans, handbooks, and crosscut reviews, assessments, and analyses.

OFCM operates with policy guidance from the Federal Committee for Meteorological Services and Supporting Research (FCMSSR). The principal work in coordinating meteorological activities and in the preparation and maintenance of OFCM reports, plans, and other documents is accomplished by the OFCM staff with the advice and assistance of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) and more than 30 program councils, committees, working groups, and joint action groups, all of whose members are Federal agency representatives.

STATUTORY BASIS FOR THE FEDERAL COORDINATION PROCESS

In 1963, Congress and the Executive Office of the President expressed concern about the adequacy of the 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, OMB) issued a report in 1963 entitled "Survey of Federal Meteorological Activities." That report described each agency's program for meteorological services and products and detailed the relationships among the programs of the various agencies. The report revealed close cooperation but little evidence of systematic coordination. Based on its survey, 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 mandated missions.

The implementation of these directives by DOC led to the creation of OFCM and the appointment of the first Federal Coordinator for Meteorological Services and Supporting Research ("the Federal Coordinator"). The Federal Committee for Meteorological Services and Supporting Research (FCMSSR) was established in 1964 to provide policy-level agency representation and guidance to the Federal Coordinator in addressing agency priorities, requirements, and issues related to services, operations, and supporting research. The FCMSSR

also resolves agency differences that arise during the coordination of meteorological activities and the preparation of Federal plans.

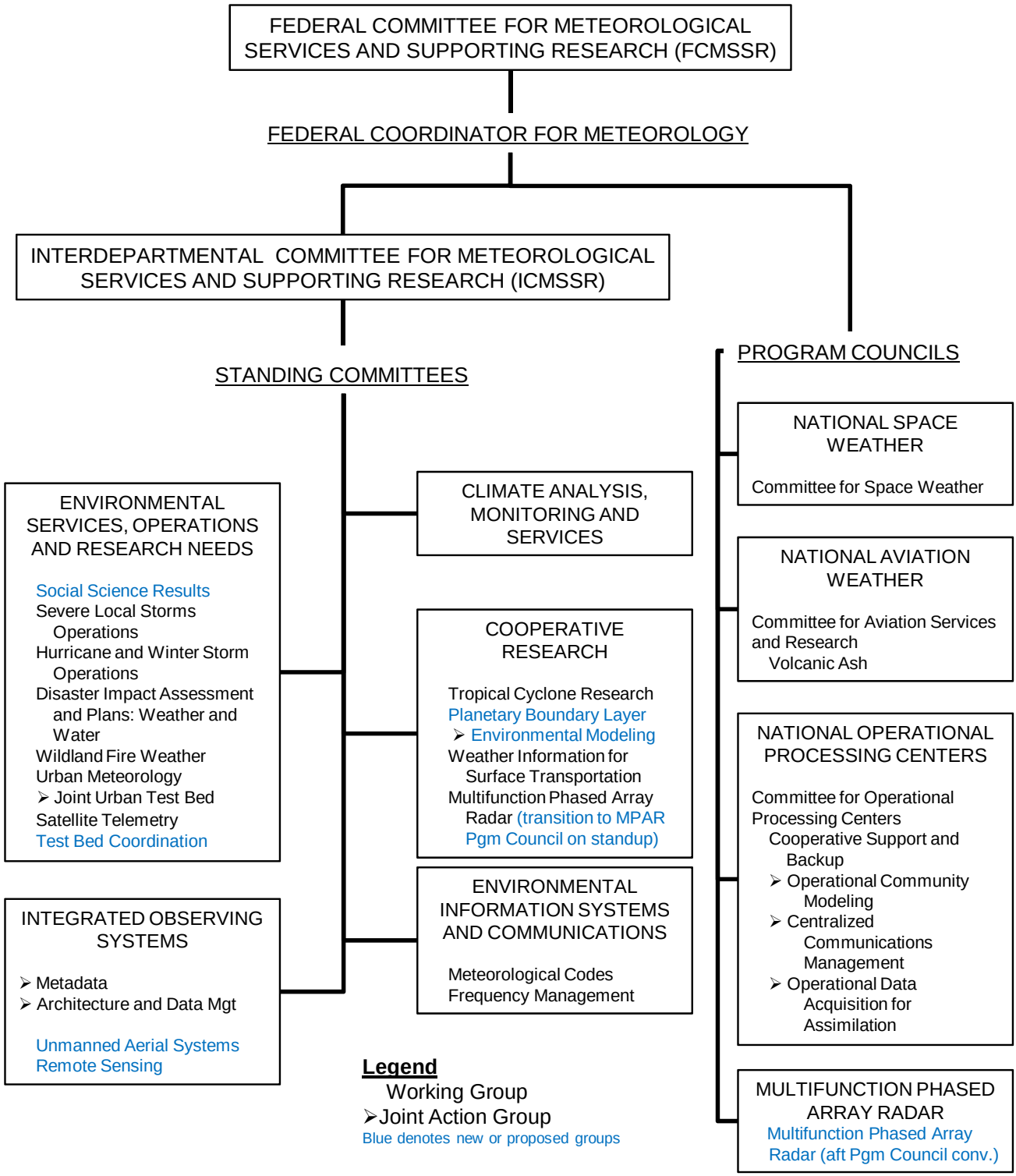
The FCMSSR comprises representatives of the 15 Federal agencies that engage in meteorological activities or supporting research, have a major need for meteorological services, or set policy and direction for such services and research. These 15 agencies are the Departments of Agriculture, Commerce, Defense, Energy, Homeland Security, the Interior, State, and Transportation; the Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), National Transportation Safety Board, and Nuclear Regulatory Commission; and OMB and the Office of Science and Technology Policy (OSTP). 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 full membership of the FCMSSR is shown on the inside cover of this *Federal Plan.*

OFCM COORDINATING INFRASTRUCTURE

Figure 2-OFCM-1 shows the current infrastructure of advisory committees, program councils, working groups, and joint action groups through which OFCM carries out its mission of ensuring the effective use of Federal meteorological resources by coordinating operational weather requirements, services, and supporting research among the Federal agencies. The FCMSSR is shown at the top of the chart, as the policy guidance advisor to the Federal Coordinator.

- The **Interdepartmental Committee for Meteorological Services and Supporting Research** (ICMSSR), which is chaired by the Federal Coordinator, is the primary program management body of the Federal coordinating structure. ICMSSR provides advice to OFCM, implements FCMSSR policies, and oversees the committees and working groups that address observing systems, weather operations and services, operational processing centers, and automated weather information systems. The full membership of ICMSSR is shown on the inside cover of this *Federal Plan.*
- The **Program Councils**, which are directly under the FCMSSR and are each chaired by the Federal Coordinator, coordinate key programs at the highest interagency policy decision-making level, and ensure that the programs meet joint requirements. In addition to establishing policy, the program councils coordinate development and oversee the preparation and implementation of national program plans, which include research and development (R&D), systems development, validation and integration, acquisition strategy, operational concepts, agency roles, and management.
- The **Committees** and their **Working Groups** and **Joint Action Groups** operate at the program and working levels to provide: (1) a forum for each agency to report activities, difficulties, and achievements; (2) a mechanism for coordinated change and problem solving; (3) a medium for collection, documentation, and consolidation of agency requirements and inventories; (4) oversight for coordinated system development; (5) a vehicle for coordinating with other groups; and (6) a mechanism for the preparation of studies, agreements, standards, protocols, reports, and national plans.

Figure 2-OFCM-1. Federal Meteorological Coordinating Infrastructure



Using these multiagency entities, the OFCM pursues the following objectives as the means for achieving its mission:

- Document agency programs and activities in a series of national plans and reports that enable agencies to adjust their individual ongoing programs and provide a means for communicating new ideas and approaches to fulfill requirements.
- Provide structure and programs to promote continuity in the development and coordination of interagency plans and procedures for meteorological services and supporting research activities.
- Prepare 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.
- Review 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.

OFCM HIGHLIGHTS FOR FISCAL YEAR 2010 AND PLANS FOR FISCAL YEAR 2011

Federal coordination activities during FY 2010 and plans for FY 2011 are discussed here under the Program Council or ICMSSR standing committee that provided oversight of the associated working group or joint action group. During FY 2010, the OFCM staff provided executive secretary and related staff support for more than 25 of these interagency groups, which held more 60 meetings during the year.

National Aviation Weather Program Council

The OFCM continues to participate in the Next Generation Air Transportation System (NextGen) Weather Working Group and the Friends/Partners in Aviation Weather (FPAW). The OFCM also 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. During FY 2011, the OFCM will be participating in two activities under the Joint Program Development Office (JPDO) for NextGen: the Weather Working Group Executive Committee and the Integrated Surveillance activity.

The Air Domain Awareness (ADA) program is an interagency homeland defense, security, and air transportation initiative that has grown out of the Federal interest in Multifunction Phased Array Radar (MPAR, see discussion below). The Federal Coordinator represented the DOC Deputy Secretary at the ADA Summit in July 2010 and continues to represent DOC in ADA working groups, fostering synergism between ADA and the DOC and NOAA roles supporting environmental awareness and frequency management.

In FY 2010, the OFCM published the *National Aviation Weather Program 10-Year Accident Reduction Initiative Final Report* on the interagency effort, under the National Aviation Weather Program Council, to reduce weather-related fatal accidents. The report describes the goals set for

the initiative, the framework for coordinating plans and programs across multiple agencies, and the actions that marshaled efforts by the Federal agencies, the private sector, academia, and non-governmental organizations to lower the general aviation weather-related accident rate by 49% and air taxi weather-related accident rates by 37%. The report also informed the agencies on areas still needing improvement to further reduce weather-related accidents.

During FY 2011, OFCM will establish a maintenance plan, as appropriate, for weather-related accident reduction gains.

In response to the volcanic ash airspace closure in Europe during 2010, the OFCM and the Working Group on Volcanic Ash coordinated interagency and international assistance to Europe and worked with the NOAA National Weather Service on actions to improve U.S. preparations for a similar event. The Working Group on Volcanic Ash has developed a clear action plan to focus research for improved volcanic ash products and services, primarily for aviation, but exportable to all applications.

During FY 2011 the Committee for Aviation Services and Research will develop an interagency long-term research strategy for volcanic ash observing and plume forecasting. This committee's Working Group on Volcanic Ash will update and maintain the National Volcanic Ash Operations Plan for Aviation, complete a needs assessment review, conduct a crosscut analysis and review of products and services that respond to volcanic ash observation and prediction needs, and support the committee in developing a long-term research strategy

National Operational Processing Centers Program Council (NOPC)

During FY 2010, the OFCM completed transition of the expiring Shared Processing Program to NOPC management. On October 7, 2009, the NOPC implemented the Environmental Satellite Data Annex to the interagency Data Acquisition, Processing, and Exchange (DAPE) Memorandum of Agreement, superseding the Shared Processing Program before its expiration in November 2009. The new annex establishes satellite data management and exchange processes among the five operational processing centers to optimize the Federal investment in environmental satellite data acquisition.

The OFCM continues to host the Committee for Operational Processing Centers (COPC) to facilitate improved processing and backup capabilities for 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 2010, the agencies with operational processing centers moved to new high-bandwidth communications network to eliminate outdated and unsupportable asynchronous transfer mode channels. The COPC network backbone that interconnects the operational processing centers was upgraded in FY 2010 from the Defense Information Switched Network Asynchronous Transfer Mode System (DATMS) to the Defense Information Systems Agency Optical Transport Network (OTN). The new connection increases throughput and link utilization and provides more robust network survivability in catastrophic events like Hurricane Katrina. This upgrade improved the operational processing centers' data communications by up to 250% and established a foundation to meet future needs.

During FY 2011, activities under COPC's Working Group for Cooperative Support and Backup will include three joint action groups. The Joint Action Group for Operational Community Modeling (JAG/OCM) will be enhancing and extending community modeling opportunities. The Joint Action Group for Centralized Communications Management (JAG/CCM) will monitor communications among the operational processing centers in order to project future infrastructure needs and plan capacity increases to meet those needs. The JAG/CCM is working with the Defense Information Systems Agency to clarify the centers' communications investment and operations planning to meet rapidly expanding needs by overseeing network sizing, cost estimates, and analysis across all five centers. The Joint Action Group for Operational Data Acquisition for Assimilation (JAG/ODAA) is developing additional annexes to supplement the DAPE Memorandum of Agreement. It will also organize and conduct the first NOPC Observational Data Conference.

National Space Weather Program Council

Based on a request in August 2008 to the National Space Weather Program Council from OSTP, the OFCM sponsored and formed the Committee for Space Environmental Sensor Mitigation Options (CSESMO) and its four supporting joint action groups. The overall study included 75 experts from 19 different Federal offices or agencies. The tasks assigned to the CSESMO included developing options and recommendations to continue solar wind monitoring and mitigate the loss of most space environmental sensing capability from the reconfigured National Polar-orbiting Operational Environmental Satellite System (NPOESS). During FY 2009, the CSESMO delivered an interagency-coordinated set of options and a recommended approach to sustain solar wind observations critical to averting adverse space weather effects. The CSESMO also delivered a coordinated mitigation strategy to provide robust space weather observing capabilities to replace those lost from NPOESS. This capability can be used to protect the reliability and effectiveness of the Global Positioning System (GPS), all satellite communications, U.S. ballistic missile defense, and satellite and manned spaceflight safety. The committee briefed its findings and recommendations to OSTP, OMB, and National Security Council staff, and OFCM prepared written reports based on both presentations.

In November 2009, the CESMO delivered the last of five deliverables to OSTP, completing all its assigned tasks on time. Overall, the CESMO reports have given OSTP a coordinated, interagency consensus set of options, recommendations, and preliminary cost estimates. These constitute solid steps toward resolving the significant risk to the electric power grid and potentially trillions of dollars in losses from lack of timely warning of a major geomagnetic storm. The CESMO deliverables led to a provision in the FY 2011 President's Budget for satellite programs to support solar wind monitoring vital to timely geomagnetic storm warnings. Specifically, the FY2011 President's Budget includes $128M for two critical space-based observing systems.

In June 2010, the National Space Weather Program Council, through the OFCM, sponsored, planned, and hosted the annual Space Weather Enterprise Forum (SWEF) to share information among Federal agency stakeholders and extend education and outreach to a wider community. The 2010 SWEF brought together more than 230 experts and stakeholders from government, science, and industry, including international participants. Media coverage and outreach surpassed that of the preceding three annual forums combined and dramatically raised awareness

of space weather and its effects—the first step in creating a more resilient society and economy. The OFCM report on the forum documents the key outcomes, which highlight needs for more education and outreach, improved planning and exercises, improvements in transitioning research results to operations, and expanded international collaboration.

Also during FY 2010, the OFCM completed, obtained OMB clearance, and published an updated National Space Weather Program (NSWP) Strategic Plan. This new plan sets directions for the next decade and will help the Nation prepare for the next solar cycle maximum. The Federal Emergency Management Agency (FEMA) became a member of the NSWP in FY 2010, building on ties of FEMA's Region VIII office with NOAA's Space Weather Prediction Center. FEMA's participation will strengthen overall NSWP and homeland security efforts to prepare for and mitigate the risks from solar storms.

NSWP activities planned for FY 2011 include the next SWEF in June 2011. The Committee for Space Weather has the following activities planned: (1) develop and implement a Strategic Communications Plan with focus on preparation for and mitigation of risks associated with the upcoming solar-cycle maximum, (2) develop and implement an action plan (near-term actions pending results from the National Research Council's Decadal Survey in heliophysics, still in progress), (3) initiate development of the new NSWP Implementation Plan, and (4) continue as executive agent for implementing the recommendations from the 2006 independent assessment report on the NSWP and for actions approved by the National Space Weather Program Council.

Executive Council for Multifunction Phased Array Radar

With the growing Federal interest in and potential for significant Federal resource commitments to MPAR, the OFCM in FY 2009 established the Executive Council for MPAR as a vehicle for senior leadership from NOAA, Department of Homeland Security, Federal Aviation Administration, Air Force, Navy, and the Department of Defense Research and Engineering office to coordinate agency activities and provide guidance for the Working Group for MPAR (WG/MPAR). The Council met for the first time in December 2008.

In November 2009, OFCM sponsored MPAR Symposium II, which had the theme "Moving Forward with Risk Reduction for Cost Effective Service Improvements." Held in Norman, Oklahoma, the symposium was attended by 230 experts from the Federal government, academia, and the private sector. The symposium delivered an effective exchange of technical information on MPAR, providing a wide community update on phased array radar technology, technical challenges, programmatic challenges, and development of a reasonable way to move forward on risk reduction. All of the symposium objectives were achieved. Featured speakers included representatives from OMB and the Joint Program Development Office for NextGen. Significant action items from the symposium included the following:

- Complete a preliminary cost-benefit analysis
- Complete a mission needs assessment
- Identify technical challenges and develop a unified R&D plan
- Investigate the MPAR relationship to the JPDO-coordinated Integrated Surveillance CONOPS

- Determine an appropriate MPAR management approach and its tie to JPDO-recommended, integrated surveillance governance process
- Exploit leveraging opportunities
- Address radio frequency spectrum allocation issues

After the MPAR Symposium II, the MPAR Executive Council met in December 2009 to review the symposium results and action items and map out near-term interagency actions in response. During FY 2011, activities planned for the MPAR Executive Council and the Working Group on MPAR (WG/MPAR) include (1) coordinating and publishing the Unified R&D Plan recommended by the symposium, (2) establishing an MPAR Risk Reduction Office and pursuing coordinated risk reduction activities, (3) planning an MPAR Symposium III for November 2011, (4) working with the NOAA Joint Radar Planning Team, and (5) converting the Executive Council to an OFCM Program Council and realigning the WG/MPAR to report to that council, rather than to the ICMSSR's Standing Committee on Cooperative Research.

Crosscutting Activities under the ICMSSR

OFCM activities described under this heading are relevant to two or more of ICMSSR standing committees (see Figure 2-OFCM-1) or are overseen directly by ICMSSR.

Interdepartmental Hurricane Conference and Tropical Cyclone/Winter Storm R&D

The ICMSSR Standing Committee on Environmental Services, Operations, and Research Needs (CESORN) oversees the Working Group on Hurricane and Winter Storms Operations. The Committee on Cooperative Research coordinates hurricane-related R&D through the Working Group on Tropical Cyclone Research.

The Working Group on Hurricane and Winter Storms Operations completed changes and coordination for the 2010 National Hurricane Operations Plan, which was published ahead of schedule on April 21. The updated plan was therefore ready well in advance of the 2010 hurricane season, enabling agencies to prepare for a potentially active season. The FEMA Lessons Learned Information Sharing electronic newsletter cited the plan, thereby reaching 55,300 subscribers directly as part of an aggressive campaign to prepare the nation for what was predicted to be an active hurricane season. Activities planned for FY 2011 include publishing an updated National Winter Storms Operations Plan, publishing the 2011 National Hurricane Operations Plan, and planning and executing an Interderpartmental Winter Storms Workshop.

During 2011, the Working Group on Tropical Cyclone Research will focus on assessing its 2010 snapshot of interagency R&D activities and publishing the results. The working group will also participate in NOAA's Hurricane Forecasting Improvement Project.

Each year, OFCM hosts an Interdepartmental Hurricane Conference (IHC) to provide a forum for the Federal agencies responsible for hurricane operations and/or supporting R&D, together with representatives of the user communities such as emergency management. IHC participants review the Nation's tropical cyclone forecasting and warning program and make recommendations to improve the program. The 64th IHC was held in Savannah, Georgia, on

March 1-4, 2010. This year's theme was *Meeting Operational Needs through Comprehensive Tropical Cyclone R&D*. For the 11th consecutive year, about 200 personnel attended, including representatives from eight Federal agencies: DOC/NOAA, Department of Defense (Navy, Air Force, Army Corps of Engineers), NASA, NSF, Department of Homeland Security (Headquarters Science and Technology, FEMA), Federal Aviation Administration (FAA), Department of the Interior (U.S. Geological Survey and the Minerals Management Service), and Department of Agriculture. Attendees also included representatives from academia, industry, and the emergency management community. Craig Fugate, FEMA Administrator, provided opening remarks to focus the conference on the ultimate goal of saving lives and protecting property. All conference objectives were achieved, and the participants identified action items to strengthen the linkages between tropical cyclone research and the needs of the operational centers. Another action item is to integrate the expertise of social scientists to improve the hurricane warning program. The 64th IHC provided a highly effective interagency update and technical exchange on improving the hurricane warning system, strengthening partnership approaches for improving services, and sharpening the focus on research-to-operations linkages. The action item from the social sciences panel provided additional impetus for the OFCM mini-workshop on social science, held in early May, 2010. An indirect outcome of this IHC was raising hurricane awareness in the Savannah region, which has a local media audience of more than 250,000. The IHC participants produced an analysis of tropical cyclone R&D activities linked to operational priorities, such as improving storm intensity forecasts and continuing to improve the 48-hour track forecast accuracy. (Hurricane track accuracy has improved by 46%—more than 60 nautical miles—over the past 10 years.)

Scientific/Technical Skill Shortages

During FY 2010, OFCM staff analyzed the results from two 2009 mini-workshops on existing and anticipated science and technology skill shortages. The first workshop was held in April 2009 and engaged agency subject matter experts in the areas of radar meteorology, space weather, atmospheric transport and diffusion, boundary layer meteorology, satellite remote sensing global, and regional numerical weather prediction modeling and data assimilation. The second workshop, in September 2009, engaged experts from the fields of agricultural meteorology and climatology, wildland fire weather, marine meteorology, and tropical cyclone operations and research.

The resulting report, *An Initial Inquiry into Meteorological Data Assimilation and Numerical Modeling Skills within the Federal Government*, summarized the arguments and evidence that the decline in personnel with data assimilation and numerical modeling skills is likely to continue, even while the demand is expected to increase. To meet the anticipated shortfall in supply, improvements in academic training are necessary. The report also recommends management process improvements to maintain necessary skill sets.

Requirements for the Joint Polar Satellite System (JPSS)

The JPSS program is intended to replace the canceled NPOESS program. During FY 2010, the OFCM staff supported development of the JPSS Level 1 Requirements Document, delivering a coordinated document in time to keep this new $12 billion program with high congressional visibility moving forward.

Committee on Environmental Services, Operations, and Research Needs

As illustrated by the list of working groups and joint action groups that fall under this committee in Figure 2-OFCM-1, OFCM's CESORN covers a wide range of basic meteorological services and supporting research.

Disaster Impact Assessments and Plans: Weather and Water Data

NOAA National Weather Service flood forecasting operations save thousands of lives and reduce injuries and property damage by billions of dollars annually. But this process, which depends on data from thousands of USGS streamgages and NOAA meteorological stations, usually does not provide data coverage sufficient to adequately document the extensive impacts of a major storm or flood or enable understanding of small-scale, localized processes. As a result, network observations have for many years been supplemented by *post-storm surveys and studies* of rainfall, flood marks, and wind damage to fill in observational gaps and obtain a more complete spatial coverage. These 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 decision makers in evacuation decisions and procedures. Post-storm data are also used to update FEMA Flood Insurance Rate Maps, revise building materials and construction standards, and improve forecasting models. The National Institute of Science and Technology and various State agencies use the data for purposes such as improving building codes and construction practices.

Today, post-storm surveys and traditional observing networks can be greatly augmented by pre-event deployment of small, self-contained instruments in spatially dense, temporary networks to monitor the event directly and continuously. Clusters of self-logging pressure transducers and real-time rapid-deployment gages monitor waves and water-levels and anemometers and truck-mounted Doppler radars monitor wind speed and direction at rapid intervals. These data describe the evolution of storms and floods with unprecedented spatial and temporal detail, particularly floods of coastal waters and wetlands. The resulting data can be used to (1) develop more accurate and robust wind, storm-surge, and flood models; (2) derive better structure design criteria and building codes; and (3) improve warning systems.

The need for a national plan for disaster impact assessments stems from recognition by several Federal agencies that they were gathering complementary and, in some cases, overlapping and duplicate weather and water data for significant storm events. These agencies desired to improve the efficiency of their individual data collection efforts, leverage the efforts of others, and share these data through an organized, inter-agency disaster impact assessment process. In 2010 the Federal Coordinator established the Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (WG/DIAP) to update and expand on the 2003 *National Post-Storm Data Acquisition Plan* by addressing not only post-storm activities but also these new technologies to pre-deploy, increase the density of, and harden observation systems, thereby providing the capability to collect and disseminate real-time data of relevance to those who forecast the events and manage Federal, State, and local response and recovery. In October 2010,

OFCM published the report from the WG/DIAP, the *National Plan for Disaster Impact Assessments: Weather and Water Data* (NPDIA). The new plan documents the types of data required, the acquisition processes, and the coordinating procedures to be used leading up to, during, and following a significant storm event. The storm events addressed in the NPDIA include land-falling tropical cyclones (hurricanes/typhoons and tropical storms), coastal extra-tropical storms (Nor'easters), severe convective outbreaks (tornadoes and windstorms), riverine and flash flooding, tsunamis, coastal and lake waves, and wind waves. The plan includes data requirements and acquisition capabilities of participating agencies, event response procedures and initiation criteria, coordination procedures, contact information, and data archival procedures. An agency response to a particular event is the responsibility of the individual agency according to its mission requirements, data needs, and available resources.

During FY 2010 and continuing in FY 2011, the OFCM continues to coordinate, as required, timely post-storm data acquisition surveys in response to natural disasters and other agency requirements, including aerial support from the Civil Air Patrol. Under the five-year Umbrella Agreement and an FY 2010 funding agreement between the OFCM and the U.S. Air Force for up to $21,000 in reimbursable support, the Civil Air Patrol flew 3 missions in support of glacial lake damming assessments in Alaska. Civil Air Patrol support for data acquisition surveys will continue in FY 2011 at a planned level of $21,000. During FY 2011, the OFCM will work with the Air Force to develop a new umbrella agreement for Civil Air Patrol support for FY 2012-2016.

Hydrometeorological Needs Assessment

In September and December 2008, the OFCM conducted two mini-workshops on hydrometeorological needs. These workshops brought together the relevant Federal agencies to discuss: (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 second workshop produced 73 operational and research needs and requirements in six categories: (1) observations, (2) modeling and forecasts, (3) education, (4) data access, (5) climate, and (6) analysis. During FY 2010, OFCM published the report, *Crosscutting Assessment of Hydrometeorological Needs—Summary Report of Two Mini-Workshops,* (FCM-R30-2010) to document the results of the workshops.

Joint Action Group on Lightning Detection Systems (JAG/LDS)

The JAG/LDS completed its tasks with publication of the report, *Federal Lightning Capabilities Requirements.* This report documents the interagency collection and prioritization of lightning data and the research needed to support a consolidated NOAA/NWS contracting effort, which can provide significant cost savings over individual agency purchases of this safety-critical information.

Wildland Fire Weather

Wildland fires have both direct and indirect effects on the urban environment. Indirect effects include degraded air quality and consequent health effects, as well as reduced visibility for both air and surface transportation. In FY 2008, the Joint Action Group for the National Wildland Fire Weather Needs Assessment, responding to a request from the Western Governors' Association, completed a needs assessment report. The needs assessment identified 47 specific needs in nine functional areas: (1) data collection, integrity, processing, and archival; (2) fire weather research and development; (3) forecast products and services; (4) modeling, prediction, and data assimilation; (5) information dissemination and technologies; (6) education, training, outreach, partnering, and collaboration; (7) user response, decision support, and resulting user impacts; (8) funding and human resources (crosscutting); and (9) socioeconomic factors.

The OFCM subsequently began developing a compilation of existing and planned Federal capabilities to meet these needs, as a first step toward identifying gaps in such capabilities. Work on this portfolio of Federal and associated governmental and fire weather capabilities, covering all nine functional areas used in the needs assessment, continued during FY 2010. Plans for FY 2011 include publishing a report on the portfolio of capabilities and establishing a working group whose fire weather-related activities will complement and support the existing interagency wildland fire management coordination infrastructure.

Workshop on the Social Sciences in Meteorological Services Delivery

In response to an action item from the 64th IHC, subsequently approved by ICMSSR, the OFCM organized an interagency exploratory mini-workshop on ways that the social sciences could contribute to more effective delivery of meteorological services. The workshop, which was held on May 3-4, 2010, was titled "Framing the Questions, Addressing the Needs: Moving to Incorporate Social Science into Meteorological Operations." Speakers included representatives from the NOAA National Weather Service, Air Force, Navy, Army Corps of Engineers, FEMA, USGS, Department of Energy, Nuclear Regulatory Commission, Federal Highway Administration, FAA, and NSF.

The OFCM assessed the results of the very informative and fruitful discussions from this workshop, presented the results to the ICMSSR in June 2010, and documented the outcome in a summary report, *Framing the Questions, Addressing the Needs: Moving to Incorporate Social Science into Meteorological Operations/Services*. Plans for FY 2011 include establishing a new Working Group for Social Science, under the CESORN, to address the recommendations from the mini-workshop and facilitate integration of social science results into meteorological products and services.

Urban Meteorology and Atmospheric Transport and Diffusion R&D

Based on the September 2004 OFCM report, *Federal Research Needs and Priorities for Atmospheric Transport and Diffusion Modeling*, the OFCM developed an atmospheric transport and diffusion (ATD) implementation strategy for those recommendations in the report for which OFCM had primary responsibility. This 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. To implement this strategy, the OFCM formed the Joint Action Group for Joint Urban Test Beds (JAG/JUTB) under the Working Group for Urban Meteorology (WG/UM).

During FY 2010, the JAG/JUTB continued work on an operational concept document for multifunctional joint urban test beds intended to provide services and data to model developers, test and evaluation personnel, and other users and stakeholders. The operational concept document includes capabilities and benefits, management structure, infrastructure requirements, selection process, implementation framework, definitions, and characteristics of urban scales. Joint urban test beds will support the following functional areas: severe weather (e.g., hurricanes, tornadoes, heat waves and cold spells, and drought), wildland fire weather, emergency response/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).

For FY 2011, the goals of the JAG/JUTB are to finalize criteria for establishing urban test beds and establish a JUTB Prototype Model Site in National Capital Region. This model site will provide a proof of concept for the operational concepts and criteria. The experience gained through its operation will provide for further refinement of the operational concept document.

On July 13-15, 2010, the OFCM cosponsored the annual George Mason University ATD Modeling Conference. The theme of this conference was enhancing model capabilities and improving the understanding of how hazardous airborne materials disperse in urban environments. In a panel session organized by the OFCM, the panel moderator and five panel members gave presentations, from both scientific and operational perspectives, on quantifying the uncertainty in ATD modeling results and predictions based on such models.

FY 2011 plans for the WG/UM include work to facilitate ATD model development, evaluation, and application. The series of ATD workshops and forums will be continued. In light of the Deepwater Horizon oil spill, the WG/UM will begin advocating for and advancing capabilities for coupled ocean-atmosphere dispersion modeling.

Working Group for Test Bed Coordination (WG/TBC)

Among CESORN plans for FY 2011 is establishing of a new working group to bring together representatives from current and emerging test bed activities, such as the Joint Urban Test Bed, Joint Hurricane Test Bed, Developmental Test Bed Center, Aviation Test Bed, Space Weather Test Bed, and Hydrometeorology Test Bed. The objectives for this WG/TBC are to facilitate exchange of science, technology, and best practices including verification, validation, and evaluation techniques; identify common problem areas and potential solutions, and facilitate common frameworks to the greatest extent possible, with the goal of fostering transition to an eventual Earth System framework.

Exploration of Products and Services Innovations

CESORN plans for FY 2011 also include exploration of innovations in two areas: a “5D Environmental Data Cloud” and new approaches for representing forecast uncertainty.

The five dimensions of the 5D Environmental Data Cloud are the three spatial dimensions, one time dimension, and one dimension for enumerating multiple variables. The planned effort will explore the 5D data concept and assess its relevance for a range of environmental/meteorological products and services in applications including aviation weather, weather information for surface transportation, wildland fire weather, observing systems, and end-user decision-support systems. Objectives include assessing applicability across the agencies involved in these application areas and developing a framework for pursuing 5D data cloud implementation.

The objectives for innovative representation of forecast uncertainty include exploring concepts for the use, presentation, and understanding of forecast uncertainty in meteorological modeling and prediction systems and in end-users' decision-making processes.

Committee for Integrated Observing Systems (CIOS)

National Network of Weather and Climate Observing Networks

The Federal meteorological community embarked on a significant new initiative for climate observing networks in FY 2009 in response to growing interest in climate trends and the 2009 publication of a National Research Council (NRC) report, cosponsored by the OFCM, entitled *Observing Weather and Climate from the Ground Up—A Nationwide Network of Networks*. In brief, the theme of this report was that the United States enjoys an effective synoptic-scale weather observing network, but society demands increasingly finer-scale weather and climate information to meet urgent needs such as predictions of atmospheric dispersion of chemical, biological, and radiological hazards from accidental releases or terrorist acts and severe weather warnings and nowcasts for urban communities. At the same time, spurred by inexpensive electronics and increasingly higher-bandwidth communications, State and local governments, corporations, academic institutions, and individuals have deployed a rapidly growing array of individual sensors and sensor networks in patchwork fashion across the country. Much of the data from these systems remain unknown or inaccessible to a wider audience of potential users.

In response to the recommendations of the NRC report, the OFCM crafted an initial framework for Federal action and gathered the stakeholder agencies in two foundational meetings held in May and July, 2009, to share information and begin developing a coordinated way forward. A refocused OFCM-sponsored Committee for Integrated Observing Systems (CIOS) provided the venue for these meetings and now oversees refinement and implementation of an overarching national strategy to integrate observational networks and systems and increase the effectiveness of current and planned capabilities.

As a result of the foundational and subsequent meetings of the CIOS, the community established the Network of Weather and Climate Observing Networks (NOWCON) initiative. In August, 2009, the Committee reported its activities to the ICMSSR and proposed NOWCON as the way ahead. The ICMSSR concurred, supported the NOWCON initiative, and approved a cochair arrangement with NOAA, DOD, DOT, and EPA representatives.

The CIOS met on November 30, 2009, and agreed on a general division of responsibility among various sectors (Federal agencies, academia, industry, individuals, State and local government,

nongovernmental organizations, and others) for each of the 15 recommendations in the NRC report. The following goals and priorities were established:

- Within 2 years, develop an inventory of observing systems, facilitate standards for observing systems to participate in the national network, develop an approach for quality assurance, explore opportunities for an integration pilot project, and develop approaches for cooperation with non-Federal stakeholders.
- Within 3 years, explore gaps, opportunities, and technologies for improving mesoscale monitoring and prediction.
- Within 4 years, develop the justification and a practical framework for cooperation, collaboration, and investment in observing systems.

At this meeting, the CIOS also approved establishment of two joint action groups and developed tasks and deliverables for them:

- The Joint Action Group on Architecture and Data Management (JAG/ADM) was tasked to survey current constructs, investigate options, and develop a concept for a flexible, extensible infrastructure of observing networks. The JAG/ADM is continuing to work on these tasks.
- The Joint Action Group on Metadata (JAG/MD) was tasked to survey existing practices and develop a flexible metadata specification or family of specifications. Near the end of FY 2010, the JAG/MD recommended a metadata standard, and the CIOS agreed in principle to work in that direction.

CIOS activities planned for FY 2011 include the following:

- Continue to address the recommendations of the NRC report and facilitate the implementation of actions that respond to the challenges in that report.
- Develop a national strategy to implement a NOWCON that is driven by validated needs and requirements.
- Working with the JAG/MD, develop a standardized, coordinated approach to metadata for the NOWCON.
- Working with the JAG/ADM, develop a coordinated architecture and data management approach for NOWCON.
- Coordinate as appropriate with the U.S. Group on Earth Observations and the NOAA Observing Systems Council.
- Interact with the American Meteorological Society (AMS) Ad hoc Network of Networks Study Group as appropriate to synchronize Federal and private sector planning and activities related to NOWCON implementation.

Unmanned Aerial Systems (UAS)

Another area of CIOS activity during FY 2011 will be to plan and execute an exploratory mini-workshop on the utilization of UAS in environmental monitoring and research. The purpose of

the mini-workshop will be to exchange information, review lessons learned from agencies operating UAS, and identify roadblocks as well as opportunities for future collaboration and coordination. The work is expected to complement the activities of the Task Force for Unmanned Systems under the Subcommittee on Ocean Science and Technology, which is part of the National Science and Technology Council structure. The outcome of the mini-workshop will help determine whether a new Working Group for Unmanned Aerial Systems is needed within the coordinating infrastructure.

Working Group for Remote Sensing

This new working group, which will also be overseen by CIOS, will have the following tasks:

- Facilitate information exchange and coordinated development of agency needs, requirements, and priorities for remote sensing capability, including environmental satellites, suborbital systems, GPSMet, radars (excluding MPAR), and other systems
- Plan and execute an exploratory mini-workshop to develop recommendations and potential courses of action to identify and address remote sensing capability gaps.

Committee on Climate Analysis, Monitoring, and Services

The OFCM supported the U.S. Climate Change Science Program (CCSP), now the U.S. Global Change Research Program (USGCRP), and actively served on the CCSP Education Interagency Working Group (EdIWG) which developed the Climate Literacy Framework. The framework was lauded by the CCSP Acting Director as "essential principles that should be included in climate science education efforts" and was then sent to OSTP for its consideration and attention. The EdIWG also authored the "Education, Training, and Public Awareness Chapter" in the UN Framework Convention on Climate Change Climate Action Report #5.

During FY 2010, the Committee for Climate Analysis, Monitoring, and Services continued work on its project examining the impact of climate-related extreme events and the observation and modeling capability available to understand and predict these events. Planned activities for FY 2011 include further development, as required, of needs and requirements for climate-related products and services.

Committee on Cooperative Research

Working Group on Tropical Cyclone Research

See heading above for Interdepartmental Hurricane Conference and Tropical Cyclone R&D, under Crosscutting Activities under the ICMMSR.

Working Group on Weather Information for Surface Transportation (WG/WIST)

The OFCM continued to advance weather services and research and development (R&D) activities supporting the surface transportation community, building on its December 2002 publication, *Weather Information for Surface Transportation--National Needs Assessment Report.* During FY 2010, the OFCM participated in the Transportation Research Board's annual meeting and continued to support the agencies' activities related to weather information and

intelligent transportation systems. Activities planned for the WG/WIST in FY 2011 include (1) integrating planetary boundary layer activities and advances to improve road weather capability. (2) coordinating with CIOS on observing systems and activities, and (3) balancing road/highway observation system efforts with additional focus on products and services for transportation system managers and users.

Planetary Boundary Layer

A new focus area for the Committee on Cooperative Research during FY 2011 will be on research needed to improve scientific understanding of the planetary boundary layer, in order to improve products and services for a range of applications (i.e., OFCM service categories) including weather information for surface transportation, wildland fire smoke management, and atmospheric dispersion modeling for airborne chemical, biological, radiological, nuclear, and explosive materials. The environmental modeling aspect of this activity will not include numerical weather prediction models such as the global and mesoscale models used by the operational processing centers (see section above on NOPC) but will instead focus on facilitating information exchange and coordinated development of agency needs, requirements, and priorities to improve modeling capabilities for dispersion, including coupled ocean-atmosphere dispersion models, fire weather and smoke, and volcanic ash.

Committee on Environmental Information Systems and Communications (CEISC)

FY 2011 activities planned for the CEISC include exploring development of a solution for PKI /certificate security needs, exploring and developing a coordinated and unified approach to Open Geospatial Consortium (OGC) standards for meteorological information services, exploring the communications and information systems issues related to the 5D Environmental Data Cloud (see discussion above under "Exploration of Products and Services Innovations"), and support the CIOS on the information services and communications aspects of the NOWCON initiative.

Working Group on Frequency Management

During FY 2011, this CEISC working group will review radio spectrum requirements for meteorological operations and services of Federal agencies, then update its white paper documenting current issues in spectrum management and proposing resolutions for them.

Working Group on Meteorological Codes

FY 2010 activities for this working group, which will continue in FY 2011, focused on coordinating standardization efforts and improvements in meteorological codes and data formats as required, e.g., XML and GRIB2 data formats.

OFCM EXTERNAL COLLABORATIONS

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 continued to participate in NRC Board on

Atmospheric Sciences and Climate (BASC) strategic planning workshops and regularly scheduled meetings. The OFCM expects to continue to participate in BASC meetings and workshops in FY 2011.

Committee on Environment and Natural Resources (CENR)

CENR Principals. The Federal Coordinator served as a member of CENR, a committee of the National Science and Technology Council, during FY 2010 and will continue to serve in FY 2011. This committee has been renamed the "Committee on Environment, Natural Resources, and Sustainability" (CENRS).

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 for Disaster Reduction, a set of implementation plans to improve the nation's capacity to prevent and recover from disasters. Space weather was identified as one of the SDR's Grand Challenges and, in FY 2007, SDR requested that the OFCM, through the National Space Weather Program, lead the effort to develop the Space Weather Implementation Plan, discussed above under activities of the National Space Weather Program Council.

American Meteorological Society (AMS)

The OFCM supports AMS activities by participating in AMS conferences and workshops and other environmental science education and outreach programs. In FY 2010, the OFCM presented two papers at the 90th AMS Annual Meeting in Atlanta, Georgia, and continued its scholarship support and collaboration with the ad hoc group on NOWCON and with the AMS public-private partnership initiative.

International Collaboration

OFCM international collaborations during FY 2010 included the 64th IHC and the 2010 Space Weather Enterprise Forum. Plans for international collaboration during FY 2011 include the 65th IHC and the 2011 Space Weather Enterprise Forum. The WG/Volcanic Ash will be supporting FAA participation in the International Volcanic Ash Task Force, which was established after the Iceland volcano eruption in summer of 2010 disrupted European air traffic.

FY 2010 OFCM PUBLICATIONS

The following publications were prepared in hard copy and/or were added to OFCM's web site (www.ofcm.gov) during FY 2010.

OFCM Publication	Date	Number
PLANS		
National Severe Local Storms Operations Plan	November 2010	FCM-P11-2010
National Hurricane Operations Plan	May 2010	FCM-P12-2010
National Winter Storms Operations Plan	November 2010	FCM-P13-2010
The National Space Weather Program: Strategic Plan	June 2010	FCM-P30-2010
National Plan for Disaster Impact Assessments: Weather and Water Data	November 2010	FCM-P33-2010
REPORTS		
Exploratory Mini-Workshop Summary Report (Framing the Questions—Addressing the Needs: Moving to Incorporate Social Science Results into Meteorological Operations/Services)	August 2010	FCM-R28-2010
An Initial Inquiry into Meteorological Data Assimilation and Numerical Modeling Skills within the Federal Government	September 2010	FCM-R29-2010
Crosscutting Assessment of Hydrometeorological Needs—Summary Report of Two Mini-Workshops	September 2010	FCM-R30-2010
National Aviation Weather Program 10-Year Accident Reduction Initiative —Final Report	September 2010	FCM-R31-2010

BASIC SERVICES

For purposes of this *Federal Plan*, Basic Services include the basic meteorological service system, to include observations, public weather forecasts, severe weather warnings and advisories, and the meteorological satellite activities of NOAA. Basic services also include the operations and supporting research of other Federal agencies that have been identified as contributing to basic meteorological services.

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

NOAA/NWS

The National Oceanic and Atmospheric Administration's (NOAA) 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. These services are provided through 122 Weather Forecast Offices (WFO), 13 River Forecast Centers (RFC), and 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 (NWR), satellite-based telecommunication systems, radiofacsimile, the media, and the internet. 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 AWIPS operational workstations are used to prepare forecasts and warnings. (NOAA Image)

The NWS uses data collection 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 air quality. Some observations are obtained through the Cooperative Observer Program, which is a nationwide network of volunteer-operated weather observing sites. These data feed sophisticated environmental prediction models running on high-speed supercomputers. The NWS' highly trained and skilled workforce uses powerful workstations to analyze all of these data to issue 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.

The NWS creates forecasts in digital formats and makes them readily available. Forecasters use their expertise to maintain an up-to-date digital forecast database of weather elements. This information is stored in the National Digital Forecast Database (NDFD). Output from NDFD is publicly available in the form of web graphics on the Internet and in several other digital formats. Outreach, education, and feedback are also critical elements to effective public response and improvements to NWS services.

The NCEP Storm Prediction Center (SPC) provides timely and accurate forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. The SPC also monitors heavy rain, heavy snow, and fire weather events across the U.S. and issues specific products for those hazards. The forecast products cover time scales ranging from a few hours out to eight days. Products issued from the SPC supply specific guidance to WFOs about the probability and intensity of hazardous weather occurrences. The NCEP experts in the area of tropical meteorology are concentrated at the Tropical Prediction Center (TPC)/National Hurricane Center (NHC). Services provided by the TPC/NHC include advisories, watches, and warnings for tropical cyclones in the north Atlantic and eastern north Pacific oceans, the Caribbean Sea, and the Gulf of Mexico, including the portions of the U.S. coastline threatened by such storms. The TPC/NHC functions both to provide guidance, coordination, and tropical weather expertise to WFO forecasters and to serve users of centrally generated products. The Pacific Tsunami Warning Center (PTWC) and the West Coast/Alaska Tsunami Warning Center (WC/ATWC) use data from 39 deep water buoys located throughout the Pacific Ocean, Atlantic Ocean, and Caribbean to conduct tsunami watches and issue warnings for all U.S. communities at risk. These watches and warnings are disseminated to WFOs, Federal and state disaster agencies, military organizations, private broadcast media, and other facilities that can furnish warning information to the public.

NWS forecasters support several health related programs such as Air Quality, Heat Health, and the Ultraviolet Index. The NWS Air Quality Forecast Services capability is an integrated, end-to-end forecast system that provides timely, reliable forecast guidance to accurately predict the onset, severity and duration of poor air quality. Forecast guidance consists of next-day ground-level ozone and smoke predictions. NOAA's partner agency, the Environmental Protection Agency (EPA), provides health-based interpretations of the forecast guidance. NOAA's products also assist state and local air quality forecasters who issue health-based air quality alerts. 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 EPA, a climatologically based ultraviolet alert is being produced for the entire Nation.

U.S. Department of Agriculture (USDA)

In FY 2001, Congress appropriated $4.989 million in funds for the USDA Weather Radio Transmitter Grant Program to facilitate the expansion of the NOAA Weather Radio into rural areas that are not covered or are poorly covered. NOAA Weather Radio alerts residents of

approaching hazardous weather and other emergencies so they may seek appropriate shelter. Available funds have been carried over each year. Through the end of FY 2009, the USDA Rural Development Telecommunication Program awarded 97 grants covering 105 sites in 27 states and Puerto Rico to 16 electric cooperatives and nonprofits, 5 telecommunications cooperatives, and 72 local and state governments from the original appropriation and residual (recovered de-obligated) funds from grant projects that were completed under budget. No funds were appropriated beyond FY 2001. Authorization of the program was reauthorized in the 2008 Farm Bill; however, no additional funding was requested.

NOAA/NESDIS

NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) operates the Nation's civil operational environmental satellite system, making constant observations of the Earth and its oceans and atmosphere. Satellite observations are collected, processed, and used to develop weather, climate, ocean, and other environmental products, services, and long-term data records that benefit the American public.

NOAA's satellites include Geostationary Operational Environmental Satellites (GOES) and Polar-orbiting Operational Environmental Satellites (POES). These two systems provide the U.S. component of a joint environmental monitoring system in partnership with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). On behalf of the Department of Defense (DOD), NESDIS also operates the Defense Meteorological Satellite Program (DMSP) spacecraft, part of the military's sixth generation of weather satellites. In addition, on behalf of the Department of Commerce, NESDIS licenses the operation of commercial remote-sensing land-imaging satellites. NESDIS also provides long-term stewardship of environmental data, managing the world's largest collection of climatic, geophysical, and oceanographic data derived from both *in situ* and space-based systems.

Polar-orbiting Operational Environmental Satellites (POES)

POES circle the Earth in a nearly north-south orbit, passing close to both poles. These satellites ensure 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 five polar orbiters. The NOAA-15, NOAA-16, NOAA-17, and NOAA-18 satellites continue to transmit data as back up and secondary satellites. Metop-A, a European environmental satellite with three instruments provided by NOAA, is the primary morning orbit satellite. Launched on February 6, 2009, NOAA-19 is the primary afternoon orbit satellite. NESDIS also manages the command, control, and communications functions of DOD's DMSP.

In addition, NOAA operates Jason-2, a joint U.S./European specialized polar-orbiting satellite. This spacecraft's mission is to provide physical data of the ocean surface, including ocean surface altimetry, sea wave height, sea wave period, surface roughness, and others. This family of products is called the Ocean Surface Topography Mission (OSTM), and is a follow on to the successful Jason-1 mission developed by the French Space Agency Centre National d'Etudes Spatiales (CNES) and NASA.

From the National Polar-Orbiting Operational Environmental Satellite System to the NOAA Joint Polar Satellite System

The President's FY 2011 budget contains a major restructuring of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) in order to put the critical program on a more sustainable pathway toward success. The satellite system is a National priority—essential to meeting both civil and military weather-forecasting, storm-tracking, and climate-monitoring requirements. As currently structured, the NPOESS program is behind schedule, over budget, and underperforming. Independent reports and an administration task force have concluded that the current program cannot be successfully executed with the current management structure and with the current budget structure.

After reviewing options, including those suggested by an Independent Review Team (IRT) and Congressional Committees, the President's FY 2011 budget takes significant new steps. In February 2010, the White House announced that NOAA and the Air Force will no longer continue to jointly procure NPOESS. This decision is in the best interest of the American public to preserve critical operational weather and climate observations into the future. NOAA, NASA, and DOD will continue to partner in those aspects of the NPOESS program where the partnership was successful in the past, such as a shared ground system and NOAA's operation of both the early morning and afternoon platforms. The restructured program eliminates the NPOESS tri-agency administrative structure and creates two programs: NOAA's Joint Polar Satellite System (JPSS) and DOD's Defense Weather Satellite System (DWSS).

NOAA and the U.S. Air Force (USAF) have already begun to move into a transition period, during which the current joint procurement will end by January 1, 2011. NASA is serving as NOAA's acquisition agent for the JPSS program and has developed a transition strategy for JPSS. While the USAF continues to have remaining DMSP polar-orbiting satellites available for launch for the next few years, NOAA launched its final polar-orbiting satellite in February 2009. Given that weather forecasters and climate scientists rely on data from NOAA's current on-orbit assets, efforts to develop the first of the JPSS platforms will focus on ensuring both short- and long-term continuity in crucial climate and weather data. In addition, these agencies have a strong partnership with Europe through EUMETSAT that will continue to be a cornerstone of our polar-orbiting constellation, and will ensure our ability to provide continuous measurements.

These changes to the NPOESS program will better ensure continuity of crucial civil climate and weather data in the future. Decisions on future satellite programs will be made to ensure the best plan for continuity of data.

Geostationary Operational Environmental Satellites (GOES)

The GOES spacecraft, in contrast to the POES spacecraft, orbit the Earth in a geosynchronous orbit, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. There are two operational geostationary satellites—GOES-East, at 75°W, and GOES-West, at 135°W—plus an on-orbit spare satellite at 105°W. Each operational satellite continuously views nearly one third of the Earth's surface. GOES-P was launched on March 4, 2010, and was renamed GOES-15 once it was successfully on orbit. GOES-15 is the third and last in the current series of NOAA geostationary satellites. GOES-15 joins the current

constellation of GOES-11 (West), GOES-13 (East), and GOES-14 on-orbit spare. GOES-12 provides for South American coverage. GOES provides continuous observations of environmental conditions of North, Central, and South America and the surrounding oceans. They provide data critical for fast, accurate weather forecasts and warnings, detecting solar storm activity, and relaying distress signals from emergency beacons. These satellites provide nearly continuous monitoring necessary for effective, detailed, and extensive weather forecasting, prediction, and environmental monitoring.

GOES Series 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 Geostationary Operational Environment Satellite Series R (GOES-R), will scan the Earth nearly five times faster, more than three times the spectral coverage and four times the spatial resolution than the current GOES. GOES-R will provide users such as meteorologists and government agencies around the world with approximately 60 times the amount of data currently provided. GOES-R is a collaborative development and acquisition effort between NOAA and NASA. In FY 2011, the GOES-R program plans to continue instrument development to meet phased instrument delivery milestones in 2012. Both the Spacecraft Preliminary Design Review and the Ground Systems Critical Design Review are planned in order to meet the 2015 launch date.

NOAA/NESDIS Data Centers

National Climatic Data Center *(NCDC)*

The National Climatic Data Center (NCDC) is the largest climate data center in the world. See Climate Services for additional details.

National Geophysical Data Center (NGDC)

NOAA's National Geophysical Date Center (NGDC) provides scientific 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. Digital databases at NGDC include more than 20 million data records. As technology advances, so does the search for more efficient ways of preserving these data. NGDC works closely with contributors of scientific data to prepare documented, reliable data sets, and continually develops data management programs that reflect the changing world of geophysics. Recent examples of NGDC's work include the creation of digital elevation models of U.S. coastal communities for prediction of potential tsunami impacts, estimation of global emissions of natural gas associated with petroleum production, and support of a future submission for extended continental shelf boundaries under the United Nations Convention on the Law of the Sea.

Natural Hazards Coastal Inundation Modeling and Mapping. Tsunamis are 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. Since 1900 more 200 tsunami events have affected the coasts of the United States and its territories causing more than 500 deaths. To improve the tsunami forecast capability and mitigate the impacts of tsunami and

other coastal flooding hazards, NGDC continues to develop high-resolution coastal digital elevation models (DEM) 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 modeling 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 DOD and the North Atlantic Treaty Organization, 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. NGDC continues to develop 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 to 2010, a three-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.

National Oceanographic Data Center (NODC)

The NODC maintains the largest collection of publicly available oceanographic data and information in the world, including hundreds of millions of records gathered from ocean observation programs conducted over the past 150 years. These data document the physical, chemical, and biological properties of the oceans, currents, weather, and biota, as observed from ships, buoys, and satellites. NODC provides access to these data to more than 270,000 users each year, including ocean researchers within NOAA, other agencies, academia, environmental program managers, educators, maritime industries, and foreign communities. Examples of these products and special-topic data sets include the World Ocean Database, the Global Argo Data Repository, the Coral Reef Information System, and the Global Ocean Data Assimilation Experiment High-Resolution Sea-Surface Temperature Project. NODC's National Coastal Data Development Center at the Stennis Space Center in Mississippi provides central access to coastal environmental data from a wide variety of sources.

NOAA/OMAO

The NOAA Office of Marine and Aviation Operations (OMAO) operates a fleet of survey ships and aircraft to support NOAA's mission goals. NOAA's ship fleet includes oceanographic and atmospheric research 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 conduct aerial surveys for hydrologic research for forecasting flooding potential from snow melt.

NOAA vessels make weather and ocean observations in the marine environment. Over 50,000 automated observations are submitted per year through the World Meteorological Organization's (WMO) Voluntary Observing Ships scheme. NOAA vessels also support NOAA's National Data Buoy Center (NDBC) in recovery of buoys that have been disabled or gone adrift.

NOAA aircraft support a broad range of meteorological activities and projects with its fleet of aircraft based at MacDill Air Force Base in Tampa, Florida. Three of its 12 aircraft are dedicated to this purpose throughout the year, providing valuable information to NOAA and the Nation.

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 forecasts and for research leading to improvements in hurricane intensity forecasts. It also supports the Hurricane Research Division (HRD) of NOAA's Atlantic Oceanographic and Meteorological Laboratory in its Intensity Forecast Experiment (IFEX), an ongoing program studying hurricane genesis, rapid intensification, and other related experiments. The G-IV is also used for winter storm surveillance in the Pacific, operating from Yokota Air Force Base, Japan; Honolulu, HI; and Anchorage, AK. Flights are in support of NCEP's ongoing program to improve winter storm forecasts in the U.S.

The NOAA G-IV annually supports Hurricane Synoptic Surveillance missions; the aircraft flies in the environment surrounding the storm at a high altitude, releasing global positioning system (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 dropsondes directly measure temperature, pressure, and humidity as they fall 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 technology are between 20 and 30 percent, resulting in a savings of $10 million or more per hurricane in warning and preparedness costs.

Two NOAA WP-3D Lockheed Orion aircraft (N42RF and N43RF) support NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations. They are equipped with a full array of state-of-the-art environmental research instrumentation. The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. 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 NOAA WP-3D aircraft, while executing the complex patterns for hurricane research, also provided 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. The stepped frequency microwave radiometers (SFMR) on the NOAA WP-3D are used to map the surface wind fields in and around hurricanes and tropical storms. Real-time surface wind speed maps are critical to providing more accurate forecasts of the extent of hurricane and tropical storm force winds. The NOAA WP-3D 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 land-falling storms. This educational outreach effort is directed at 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 operated 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 each hurricane season, the two NOAA WP-3Ds support several major research experiments in support of NOAA's Hurricane Research Division. They also support HRD and EMC's program to obtain 3-dimensional horizontal wind fields in developing tropical systems and hurricanes, utilizing their tail Doppler radars (TDR). The objective of this effort is to obtain data that can be assimilated into the HWRF hurricane forecast model for the purpose of improving intensity forecasts.

The NOAA WP-3D's 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-3D's, equipped with microwave scatterometers and radiometers, provide under-flight validation of European ASCAT and Indian OceanWind2 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.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

National Science Foundation (NSF)

To improve weather forecasts and public safety, the NSF supports basic research on observational systems, analysis techniques, and understanding of phenomena. Ongoing research on new observational systems includes techniques for using cosmic ray data to derive soil moisture and using distributed, short-wavelength radar systems for small-scale severe weather observations. Major efforts to understand tornadoes and hurricane genesis are ongoing, and aim to improve the ability of weather forecasters to relay high-impact weather information to the public.

NOAA/NWS

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. NCEP's Environmental Modeling Center (EMC) develops, enhances, and maintains complex data assimilation and numerical modeling software systems that span the

globe. The computer models and other numerical forecast products developed by the EMC provide the basic guidance that NCEP and WFO meteorologists use in making weather and climate predictions. The EMC uses advanced modeling methods developed both 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 National Aeronautics and Space Administration (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 resulted in improvements to mesoscale and global models, as well as advancements in hurricane track forecasts, climate forecasts, and air quality forecasts.

NOAA/NESDIS

Center for Satellite Applications and Research (STAR)

STAR is the science arm of NESDIS. Its mission is to create satellite data products using observations of the land, atmosphere, and ocean and transfer those products from research into routine operations. In addition, STAR supports the assimilation of the data from new satellite instruments into NOAA's numerical prediction models. STAR also calibrates the Earth-observing instruments of all NOAA satellites to provide reliable measurements for assessing the current conditions on Earth in a timely manner, predicting changes in conditions and studying long-term trends in the environment.

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.

Satellite Research Projects

Hurricane Applications of Lightning Measurements. The next-generation NOAA geostationary satellites, starting with the GOES-R, will be capable of measuring total lightning. Lightning causes between $4 and $5 billion in losses each year in the civilian sector with about 47 deaths and 303 injuries per year. Although ground-based lightning measurements have been available for several years, this will be the first time that these data are 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 2011 will continue to focus on the continued use of a new ground-based lightning network that can provide some information of lightning activity over the tropical oceans. The World Wide Lightning Locator Network (WWLLN) provides estimates of only about 25 percent of the lightning activity compared to what will be available from GOES-R, but it provides a first look at the forecast potential of this new data source. The WWLLN data is being 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. Preliminary results for the Atlantic are very encouraging and show the potential to use lightning information to improve the prediction of rapid intensity change, which is an especially challenging forecast problem. Ongoing research will generalize this study to tropical cyclones in other ocean basins outside of the Atlantic and the development of experimental rapid intensification forecast algorithms that utilize the WWLLN data.

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 warnings, which are important for evacuations and other mitigation activities.

Precipitation Estimation from Satellites. Precipitation estimation data from satellites provide a critical supplement to other sources of rainfall information for flood and flash flood forecasting, water resources applications, and myriad other uses—in many parts of the world, satellites represent the only reliable source of rainfall information. Infrared and visible data from geostationary weather satellites provide high-resolution, rapidly updated rainfall information for hazardous weather applications. More accurate estimates of rainfall can be derived from microwave-frequency data onboard polar-orbiting satellites, but their less-frequent updating makes them more suitable for longer-term water monitoring.

In FY 2010 and into FY 2011, NOAA expects to complete the transition of three research products to operational status and will develop the algorithms for the next generation of NOAA's GOES. The three products are current rainfall rate, which will build on a nearly 20-year legacy of automated satellite rain rate products; three-hour rainfall potential, which will be a brand new product predicting rainfall from satellite data; and three-hour rainfall probability—the probability of measurable rainfall during the next three hours. In addition, modifications to the current-generational algorithms will be explored in order to better serve the users of these data.

Microburst Assessment from Satellites. A suite of products was developed and evaluated to assess hazards presented by convective storms and associated high winds to aircraft in flight derived from the current generation of GOES. The existing suite of GOES microburst products employs the GOES sounder to calculate risk based on conceptual models of favorable environmental profiles for convective wind generation. Large output values of the microburst index algorithms indicate that the ambient thermodynamic structure of the troposphere fits the

prototypical environment for each respective microburst type (i.e. Wet, Hybrid, Dry, etc.). In accordance with new diagnostic nowcasting products, the Microburst Windspeed Potential Index (MWPI), and a multichannel GOES imager microburst risk product were recently developed and experimentally implemented. These products are designed to infer attributes of a favorable microburst environment that include large temperature and moisture changes with height in the atmosphere. These conditions foster intense convective downdrafts due to evaporational cooling as precipitation descends in the sub-cloud layer.

The GOES imager microburst risk product is based on a multichannel algorithm in which output brightness temperature difference is proportional to microburst potential. This product provides a higher spatial (4 km) and temporal (30 minutes) resolution than is currently offered by the GOES sounder microburst products (10 km, 60 minutes) and thus, provides useful information to supplement the sounder products in the convective storm nowcasting process. In addition, this imager product provides microburst risk guidance in high latitude regions, especially north of latitude 50°N, where existing sounder coverage is not available. FY 2011 research will continue to focus on intercomparison, validation, and refinement of the GOES microburst products as well as training in the operational use of the products.

NOAA Office of Oceanic and Atmospheric Research (OAR) Laboratories

Air Resources Laboratory (ARL)

ARL conducts research and development in the fields of air quality, atmospheric dispersion, and climate. Key activities include the development, evaluation, and application of air quality models; improvement of approaches for predicting atmospheric dispersion of hazardous materials; and the generation of new insights into air-surface exchange and climate variability and trends. The goal of ARL's work is to conduct research that can improve the Nation's ability to protect human and ecosystem health. (see Emergency Response and Homeland Security Services)

Earth System Research Laboratory (ESRL)

ESRL is taking a lead 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 of these missions is to evaluate the utilization of UAS's 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 UAS's (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, aerosols, 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. ESRL's Global Systems Division (GSD) is conducting global and regional Observing System Simulation Experiments (OSSE) to evaluate the potential benefits of UAS sampling of hurricanes and their environment.

Scientists at GSD have 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 NWS for high impact weather events. This system collects and processes observations from over 250 GPS-Met stations, owned and operated by NOAA and other government agencies across the U.S., and the data is distributed by GSD using a web interface. When funds are available, this system will be transferred to NWS 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, and so that the system can be incorporated into weather prediction models. In the process of developing this capability, NOAA research discovered that 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. In addition, the GPS-Met observations for water vapor, an important greenhouse gas, were discovered to be both 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 to verify and confirm climate model predictions.

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 Science 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.

Other important areas of research within ESRL include tropical atmospheric research, numerical analysis and prediction modeling, and atmospheric chemistry and atmospheric boundary layer processes.

National Severe Storms Laboratory (NSSL)

NSSL seeks to improve the accuracy and timeliness of forecasts and warnings of hazardous weather events such as blizzards, ice storms, flash floods, tornadoes, and lightning. NSSL accomplishes this goal through a balanced research program, which aims to: (1) advance the understanding of weather processes; (2) improve forecasting and warning techniques; (3) develop new forecast and warning techniques and applications and evaluate them for operational use; (4) transfer knowledge, techniques, and applications to the NWS and other agencies; (5) develop enhancements for the Weather Surveillance Radar-1988 Doppler (WSR-88D), the cornerstone of the radar network now operated across the United States; (6) develop new radar technologies (e.g., dual-polarization and phased-array radar); and (7) conduct field programs that use mobile, in situ, and remote observational capabilities to collect data that support theoretical research. NSSL performs research in three primary areas: weather radars, high-impact hazardous weather, and storm-scale hydrometeorology.

Weather Radar Research. The NSSL is known for research leading to better understanding of severe weather and the development of related observational capability, both remote and in situ, and in particular for its role in the development of the WSR-88D radar. NSSL continues to

improve the WSR-88D software algorithms used by the NWS forecasters. NSSL is assisting in the NWS deployment of the dual polarization upgrade to the WSR-88D and is engaged in a risk reduction activity for the Multifunction Phased Array Radar (MPAR) technology. In FY 2011, NSSL, in collaboration with the FAA, is planning a Technology Assessment Program (TAP) to engage industry in helping design a polarized phased array radar to be tested in FY 2011-2013 as part of the TAP risk reduction plan. Over the next 10 to 15 years, a network of MPAR units could provide the next-generation expansion of our current weather radar 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.

In the spring of 2011, forecasters from the NWS Eastern, Central, and Southern Regions will bring their warning decision making expertise to Norman, OK, to participate in the Phased Array Radar Innovative Sensing Experiment (PARISE). One question driving research with the Phased Array Radar (PAR) Program is whether faster data updates will increase warning lead time. NSSL is conducting experiments to directly compare warnings based on data provided at current radar update rates with warnings issued based on faster data update rates provided by PAR technology. Teams of forecasters will use two different PAR data sets. One with the faster data update rate typical of the PAR and the other with PAR data, but updated at the WSR-88D rate. This provides a basis from which warning lead times can be compared with no differences in data, just update time and the warning decision process used by each team. In addition to learning about impact of temporal sampling on warning decision making, PARISE will evaluate data processing and collection techniques unique to the NSSL's PAR Program, such as electronic adaptive scanning and scheduled scanning, that are adapted to the user's needs.

The MPAR technology 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 for severe weather from six minutes for WSR-88D 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.

High Impact Hazardous Weather Research. 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.

In FY 2010, NSSL helped lead the Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2)—the largest and most ambitious field experiment in history to explore tornadoes. VORTEX2 was a $14 million field program supported by NOAA and the National Science Foundation (NSF). Nearly 100 scientists and students from 16 different universities and various other academic organizations in the U.S. took part in the experiment. VORTEX2 also involved forecasters from the NOAA NWS forecast offices, the NOAA Storm Prediction Center, Environment Canada, the Australia Bureau of Meteorology, and Finland. The VORTEX2 teams were looking to understand how, when, and why tornadoes form. Answers to

these questions will give researchers a better understanding of tornadoes and should help increase warning time for those in the path of these deadly storms. In 2009, data was collected on 11 supercells, with probably 4 cases worthwhile for scientific exploration. In 2010, data was collected on many more storms, including tornadic storms in and around central Oklahoma that produced a rich data set that included MPAR radar data and data from the smaller scale Collaborative Adaptive Sensing of the Atmosphere (CASA) radars, funded by NSF.

NSSL is working with the NWS to develop a vision for the warning decision process, which continues to evolve as scientists and engineers work toward integrating the next generation radar (e.g., rapid scanning phased array radar) and storm-scale numerical models to create a storm-scale prediction capability for the NWS. Beginning in FY 2010, NSSL received funding to support the "Warn on Forecast (WoF)" program. Within the next decade, NSSL envisions operational units using a WoF 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. The WoF program is being conducting in collaboration with the Earth Systems Research Laboratory Global Systems Division (ESRL/GSD), the NWS Storm Prediction Center, and the NWS Norman Forecast Office.

Storm-scale Hydrometeorology Research. The Coastal-Inland Flood Observation and Warning (CI-FLOW) project uses NSSL's multi-sensor rainfall estimates to drive an NWS distributed hydrologic model that predicts streamflow to help NWS improve flash flood warnings. CI-FLOW is a major component of NOAA's Integrated Water Forecasting program called Coastal, Estuary Resource Information System (CERIS). In addition to the streamflow prediction, streamflow data from predictive models are used to drive storm surge models from North Carolina State University and the University of North Carolina. We believe this system of coupled models, tested during the 2010 hurricane season, can be used not only for inundation studies of landfalling tropical systems, but also for land-use studies, algal bloom studies, and water quality assessments studies.

Atlantic Oceanographic and Meteorological Laboratory (AOML)

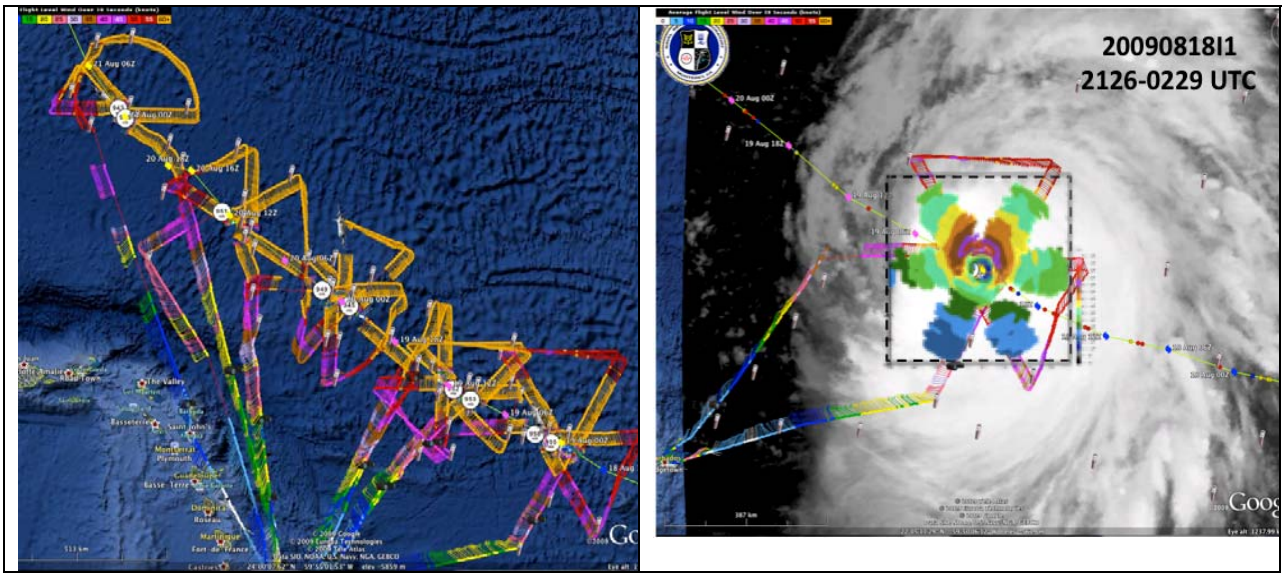
Ocean Observing Technologies. In addition to the many weather-related observing systems, OAR is dedicated to improving the development, deployment, and monitoring of oceanographic-related observing technologies and related data. As part of this effort, AOML manages the deployment of drifting buoys around 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 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. Approximately 100 meteorological drifting buoys are maintained in the Southern Hemisphere as part of the Southern Hemisphere Drifting Buoy Program—a subset of the Global Drifter Program.

NOAA supports measurements from thermosalinographs (TSG) which are mounted close to the water intake of research and cargo ships and continuously measure the sea surface salinity and temperature along the track of the ship. 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 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, NOAA, University-National Oceanographic Laboratory System (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.

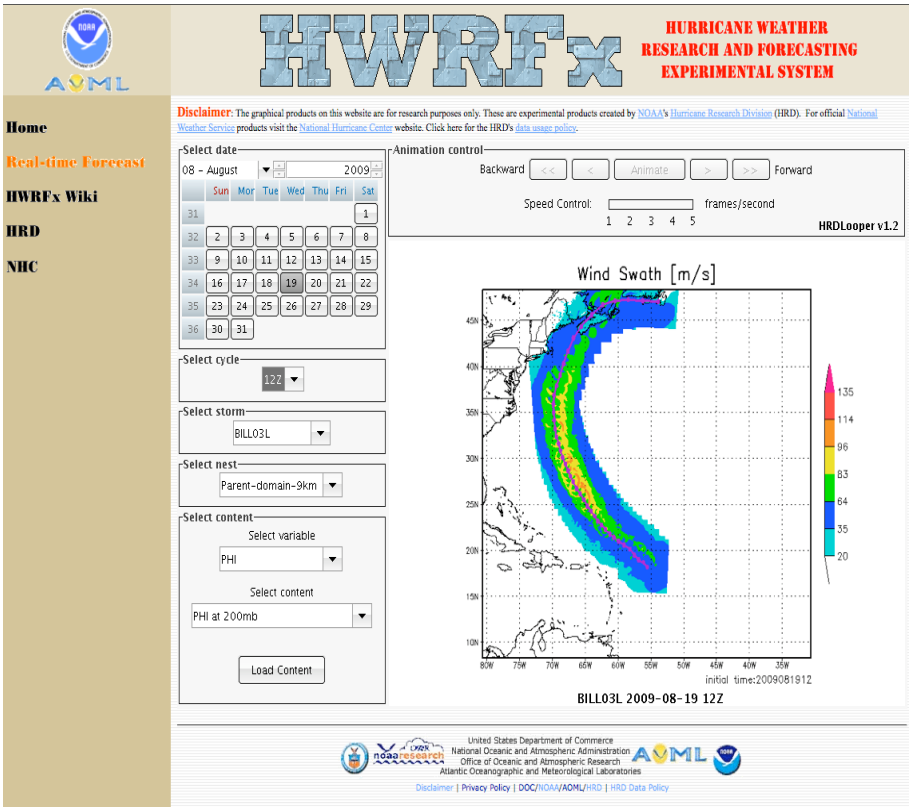
AOML operates a global Expendable BathyThermograph (XBT) Program that utilizes approximately 30 ships of the SOOP and collaborates with international institutions that operate another 30 ships to monitor the global upper ocean thermal structure. TSG and XBT data are placed in real-time onto the GTS and are being used to initialize weather and climate forecast models.

Tropical Cyclone Research. The capabilities of AOML's Hurricane Research Division (HRD) 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). An aircraft field program is used to gather data sets gathered at all stages of the storm's lifecycle, which are used to support operational needs and form the cornerstone of HRD's research. 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, and provide NOAA a unique capability.



On the left is an image of the flight patterns for five consecutive back-to-back WP-3D Doppler mission around from 00Z 19 August 2009 in Hurricane Bill. On the right is a depiction of the real-time Doppler analyses for three legs on the first of the five missions showing the flight track and Doppler analyses superposed over an IR satellite image centered on the mission time. The Doppler radar data collected on these three legs were used to generate superobs for assimilation into the ARW model running on TACC

Much of the research at HRD is focused on improving 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 tropical cyclone forecasting model system—the Hurricane Weather Research and Forecasting (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 Hurricane Forecast Improvement Project (HFIP).



Real-time maximum surface wind swath produced by the HWRFx model for Hurricane Bill on 0000 UTC 19 August 2098. The track is depicted in magentat with dots long the track every 3 h.

Researchers at HRD, together with 1-2 researchers at the GFDL, 6-7 researchers at ESRL, and 3-4 researchers at NESDIS/ORA make up the NOAA core capability for hurricane research and development and is a major part of the NOAA HFIP. HFIP is built 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 unified 10-year NOAA 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 percent, 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 percent for Days 1 through 5.
- Reduce average intensity error by 50 percent for Days 1 through 5.
- Increase the probability of detection (POD) for rapid intensity change to 90 percent at Day 1 decreasing linearly to 60 percent at Day 5, and decrease the false alarm ratio (FAR) for rapid intensity change to 10 percent for Day 1 increasing linearly to 30 percent at Day 5.
- Extend the lead time for hurricane forecasts out to Day 7.

Although 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.

While the vast majority of HRD's research efforts are directed through HFIP toward improving observations, analysis, and model guidance and transitioning those improvements into operation, a number of research areas are not as well developed and require more basic research, often in collaboration with university collaborators. HRD is pursuing three such efforts: (1) improved understanding of the air-sea energy transfer processes related to waves, spray, and upper-ocean mixed layer in partnership with collaborators from UM/RSMAS, URI, and NRL; (2) improved understanding of the role of aerosol and microphysical processes in collaboration with URI and University of Tel Aviv; and (3) improved understanding of land surface impacts on rainfall and flooding through collaboration with Purdue.

Geophysical Fluid Dynamics Laboratory (GFDL)

The Geophysical Fluid Dynamics Laboratory (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 and climate 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 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. Recent research using these models has exposed a potential breakthrough in predicting seasonal hurricane activity: atmospheric models forced with observed sea-surface temperature can skillfully predict the interannual variability of the number of hurricanes in the Atlantic, showing that the random part of this annual Atlantic hurricane frequency (the part not predictable given the SSTs) is relatively small.

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.

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 GFDL 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 prediction 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.

Great Lakes Environmental Research Laboratory (GLERL)

In FY 2011, GLERL's planned research programs in coastal hydrodynamic modeling, hydrology, coastal buoy technology, regional climate modeling, and ice forecasting will directly support NOAA's meteorology mission through improved marine forecasts, more accurate watershed models, augmented real-time marine observations, better estimates of regional climate impacts on weather in the Great Lakes, and a whole new approach to ice forecasting.

Pacific Marine Environmental Laboratory (PMEL)

Meteorological research at PMEL focuses on air-sea interaction research in the Gulf of Alaska and Bering Sea, as part of PMEL's Ecosystem-Fisheries Oceanography Coordinated Investigations (EcoFOCI) project, conducted jointly with NOAA's National Marine Fisheries Service (NMFS)/Alaska Fisheries Science Center. Financial support for the research is provided by NOAA, NSF, and the North Pacific Research Board (NPRB).

PMEL also collaborates with ESRL/CSD on the Health of the Atmosphere air quality research effort. In 2010, PMEL led the CALNEX marine sampling program aboard the R/V *Atlantis* off the southern and central California coasts**.** PMEL's ocean climate research programs collect surface meteorological data from moored buoys and report in near-real time for ingest into global models. Data from PMEL's PIRATA and RAMA tropical observing systems in the Atlantic and Indian Oceans, and from PMEL's ocean climate stations at Ocean Weather Station Papa (Gulf of Alaska) and the Kuroshio Extension Observatory (KEO) in the Northwest Pacific report surface meteorological data. A third ocean climate station is scheduled to be established early in 2011 in the Aghulas Current off the southeast coast of Africa.

Interagency Research Programs

The United States Weather Research Program (USWRP)

The USWRP is an interagency weather research and transition of research to application program. The member agencies include: NOAA (lead), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Navy, and the Air Force. The NOAA component of USWRP has been quite active although the funding levels have been flat. NOAA's Office of Oceanic and Atmospheric Research (OAR), through OAR's Office of Weather and Air Quality, helps plan NOAA USWRP priorities, implements the program, and monitors progress.

The Developmental Test Center (DTC). The DTC (http://www.dtcenter.org/index.php) is a joint operation between NOAA/Earth System Research Laboratory/Global Systems Division and the National Center for Atmospheric Research in Boulder, CO, funded by NOAA. It serves as the test bed for the Weather Research and Forecasting (WRF) community model (http://wrf-model.org/index.php), which is a cooperative venture between NOAA, NSF, the Air Force, and the Navy. In FY 2011, the DTC will continue to develop the Hurricane Weather Research and Forecasting (HWRF) community model.

Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information (Societal Impacts Program or SIP). The USWRP provides most of the support for SIP (http://www.sip.ucar.edu/) and will continue to do so in FY 2011. 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. In FY 2011, the SIP will continue work to determine the public understanding of forecast uncertainty and to research the communication of hurricane forecast information from the National Hurricane Center, through the various communications outlets, to the public and to emergency managers. They will also be looking at what information the public uses for hurricane evacuation decisions. 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 Joint Hurricane Testbed (JHT). The NOAA USWRP provides total support for the 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. This project is located at the NWS's National Centers for Environmental Prediction (NCEP) Tropical Prediction Center in Miami, FL. The USWRP will continue to fully support the JHT in FY 2011. Recently, the JHT has been emphasizing improving forecasts of hurricane intensity at landfall. In FY 2011, the JHT will be beyond the middle of its fifth cycle of two-year awards. This cycle has 11 awards.

The Hydrometeorological Testbed (HMT). NOAA USWRP has invested in research and transition of research to applications to improve quantitative precipitation forecasts through NOAA's HMT (http://hmt.noaa.gov/), led by OAR's Environmental Systems Research Laboratory's (ESRL) Physical Sciences Division (PSD). The HMT seeks to improve regional

precipitation forecasts, particularly for heavy, flooding rains. This support will continue as the HMT moves to set up a field program in the southeast U.S. as it moves from the west coast. This project also collaborates with OAR's National Severe Storms Laboratory (NSSL).

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). The U.S. representative to the THORPEX international management committee resides in NOAA and NOAA is the lead U.S. agency for 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, and NOAA USWRP and NCAR support activities within the third bullet. 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 U.S., Canada, and Mexico (as a user). NAEFS is an important component of the THORPEX Interactive Forecast System (GIFS), and a fully implemented GIFS will be available by the end of the THORPEX program period in about 2014. 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 provides U.S. support for the socioeconomic component of THORPEX. THORPEX is a key component of ensemble, 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.

In FY 2011, progress will be made on the GIFS by continuing international agreements on data access, types of model data to be made available, and how the data will be disseminated. NAEFS may add some members to the ensemble with the US Navy having joined NAEFS in FY 2009. The current internal NOAA awards for THORPEX research will be reviewed and priorities for such research will be adjusted as THORPEX begins to focus partially on shorter term mesoscale and local ensembles.

Joint Center for Satellite Data Assimilation

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, 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 U.S. 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.

AGRICULTURAL AND LAND MANAGEMENT METEOROLOGICAL SERVICES

For purposes of this *Federal Plan*, Agricultural and Land Management Meteorological Services are 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 land areas. Meteorological services specifically tailored for wildland fire management are reported under the Wildland Fire Weather service category.

OPERATIONAL PROGRAMS INCLUDING PRODUCTS AND SERVICES

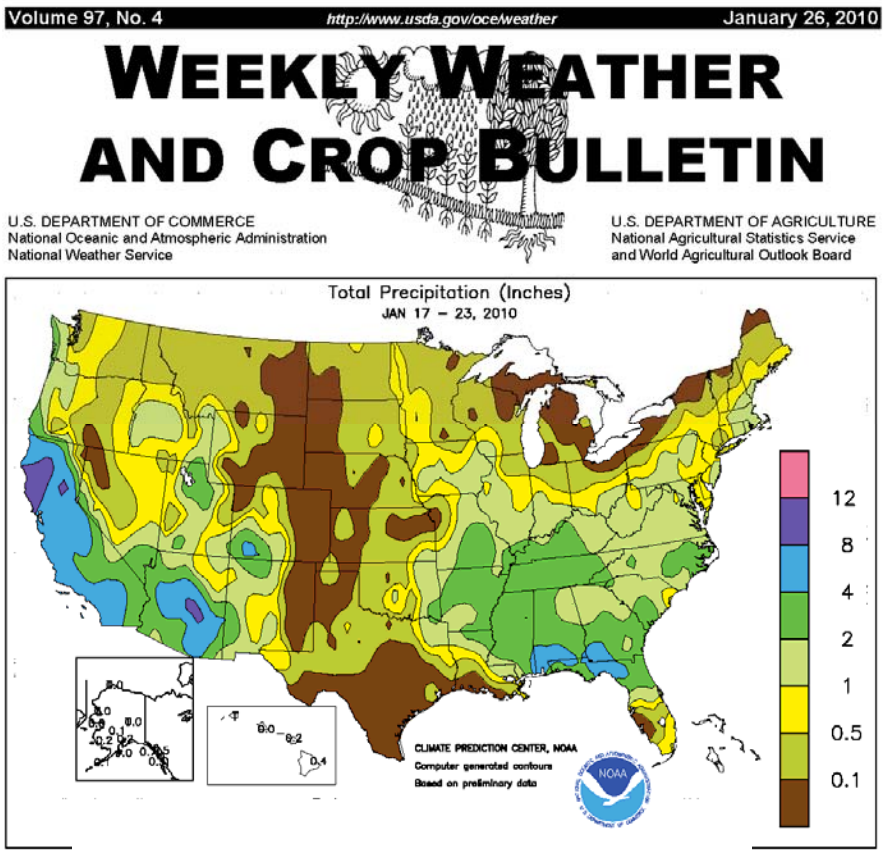
U.S. Department of Agriculture (USDA) Agricultural Services

The U.S. Department of Agriculture (USDA) Office of the Chief Economist (OCE) World Agricultural Outlook Board (WAOB) serves as the USDA's focal point for economic intelligence and commodity outlook for U.S. and world agriculture. The WAOB coordinates the official USDA domestic and international commodity estimates each month. One of the primary responsibilities of the WAOB is to coordinate, review, and approve the *World Agricultural Supply and Demand Estimates* report. The WAOB maintains the integrity of this report by ensuring all information used to prepare the report is consistent, objective, and reliable. The WAOB also coordinates all weather and climate information and monitoring activities within the USDA. Because weather and climate have a significant impact on agricultural production, the WAOB employs meteorologists who specialize in preparing agricultural weather assessments. This activity is conducted at the Joint Agricultural Weather Facility (JAWF) which is located within the OCE/WAOB and serves as the USDA's focal point for weather and climate information.

The JAWF was created in 1978 as an operational unit and is a cooperative effort between the WAOB and the Department of Commerce (DOC)/National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS)/National Centers for Environmental Prediction (NCEP)/Climate Prediction Center (CPC). The primary mission of the JAWF is to routinely collect global weather data and agricultural information to assess the impact of growing season weather conditions on crop and livestock production prospects. The JAWF receives a full suite of data and products from the NWS, and JAWF meteorologists combine and carefully analyze these agrometeorological data daily, preparing real-time agricultural weather assessments in the process. Some of the meteorological information that the JAWF meteorologists utilize include surface weather observations, radar data, satellite imagery, and model output. These meteorological data are regularly imported into a geographic information system (GIS) along with agricultural data to facilitate global agrometeorological analyses and to help identify regions of concern. These assessments keep USDA commodity analysts, the OCE, and the Secretary of Agriculture and top staff well informed of weather impacts on crops and livestock worldwide. In addition to providing routine agricultural weather assessments, JAWF meteorologists prepare special assessments when extreme weather (e.g., droughts, heat waves,

freezes, floods, and hurricanes) has been observed or is imminent. Many of these special assessments are also prepared using GIS to overlay agricultural and meteorological data. In recent years, the NWS, National Hurricane Center (NHC), CPC, and the Hydrometeorological Prediction Center have supported the JAWF by providing an increasing number of their operational products in GIS-compatible formats. This effort has significantly increased the speed and efficiency with which agricultural weather assessments can be prepared and has enabled JAWF meteorologists to more accurately assess the impacts of weather on agriculture. When integrated with other data, these routine and special crop-weather assessments and analyses provide critical information to USDA decision makers, preparing crop production forecasts, formulating trade policy, and coordinating disaster relief.

The 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). Additionally, the JAWF obtains data from the NWS Cooperative Observer Program (COOP) to support domestic agricultural weather applications. The WMO and COOP data are archived at WAOB using an Oracle database management system. This sophisticated data warehouse helps JAWF meteorologists to manage the numerous agrometeorological data sets used for agricultural weather assessments.



A JAWF Weekly Weather and Crop Bulletin cover

The JAWF's flagship publication is the *Weekly Weather and Crop Bulletin (WWCB)*. The WWCB is jointly produced by the WAOB, the National Agricultural Statistics Service (NASS), and the CPC. First published in 1872 as the *Weekly Weather Chronicle,* the publication has evolved over the past 138 years to become a vital source of information on weather, climate, and agricultural developments worldwide. The *WWBC* highlights weekly meteorological and agricultural developments on national and international scales, via numerous maps, charts, tables, and text products. These products combined provide a comprehensive illustration of the weather and climate conditions affecting agriculture, benefiting USDA decision makers and the agricultural community. The *WWCB* also provides timely weather and crop information relevant to the

monthly *Crop Production* and *World Agricultural Supply and Demand Estimates* reports, issued by USDA/NASS and USDA/OCE/WAOB, respectively.

Knowledge of historical weather and climate patterns and past agricultural production in major agricultural regions worldwide is critical to the success of the JAWF's agro-meteorological assessments. In September 1994, OCE/WAOB/JAWF published the *Major World Crop Areas and Climatic Profiles* (Agricultural Handbook No.664) book. This reference handbook provides the framework for assessing the weather's impact on world crop production by providing information on climate and crop data for key producing regions and countries. An electronic version of the handbook was developed to provide periodic updates to the printed version as additional data become available. Coverage includes major agricultural regions and crops, including 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 *Weekly Weather and Crop Bulletin* and *Major World Crop Areas and Climatic Profiles* book and other JAWF publications are available online at http://www.usda.gov/oce/weather.

Drought is one of the most costly natural disasters affecting the United States. In the summer of 1999, the U.S. Drought Monitor (USDM) was developed to help improve drought assessments in the United States. The USDM is a collaborative effort between Federal and academic partners, including the University of Nebraska-Lincoln National Drought Mitigation Center (NDMC), JAWF, CPC, the NOAA/NESDIS/National Climatic Data Center, and the Desert Research Institute. Approximately 11 lead authors, two of whom work for the JAWF, rotate the responsibility of preparing the USDM. Produced weekly, the USDM is a synthesis of multiple indices and impacts depicted on a map and in narrative form. The NDMC 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 GIS format, it is often overlaid on agricultural data to illustrate and quantify the spatial extent of drought, affecting various agricultural commodities. These agricultural weather products, along with the USDM, serve as the main source of information for briefing USDA top staff on U.S. drought developments.

Similarly, the North American Drought Monitor (NADM) is a cooperative drought monitoring effort among drought experts in Canada, Mexico, and the United States. The NADM was initiated at a workshop in April 2002 and is part of a larger effort to improve the 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 USDM collaborators, as well as 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) builds upon existing drought monitoring tools and experiences, such as the USDM, to develop an early warning system that aids in drought preparation and mitigation. The recommendations for such an early warning system were outlined in a 2004 report from the Western Governors' Association (WGA) entitled, *Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System*. The OCE is one of several USDA agencies that have taken a lead role in the development of NIDIS, working closely with NOAA—the lead Federal agency—and

the WGA, to address the specific needs of the agricultural community. Specifically, WAOB represented USDA on the NIDIS program implementation team, which is comprised of Federal and state agencies, academia, and the private sector and was established to develop a NIDIS implementation plan. The NIDIS implementation plan was released in June 2007, describing the NIDIS implementation strategy and governance structure. One of the early deliverables of NIDIS is the Drought Portal (http://www.drought.gov), which serves as the government's multi-agency drought interface. The WAOB is working with other USDA agencies to provide relevant drought information to the public via the Drought Portal.

The USDA's Chief Meteorologist is currently serving as past-president on the Management Group of World Meteorological Organization's (WMO) Commission for Agricultural Meteorology. In this position, he advises the president on projects related to impacts of natural disasters and extreme events on agriculture, and the adaptation of climate change/variability to agriculture. The Chief Meteorologist promotes the development of new technology and information services for agriculture. One major accomplishment is the World AgroMeteorological Information Service (WAMIS), which is a dedicated web server that hosts agrometeorological bulletins and advisories issued by WMO members for the global agricultural community, and also provides training modules to aid members in improving their agrometeorological products. The WAMIS web site is: http://www.wamis.net.

Bureau of Land Management, Land Management Services

The Department of Interior's (DOI) Bureau of Land Management (BLM) utilizes air-resource-related (air quality, weather, and climate) information in order to manage public lands in a manner consistent with Congressional direction as expressed in the Federal Land Policy Management Act (FLPMA). FLPMA directs the BLM to periodically and systematically inventory resources through a land-use planning process and to manage public lands in a manner that protects the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resources, and archaeological values. The BLM also requires air-resource-related information to conduct environmental analyses under the National Environmental Policy Act (NEPA) for agency-initiated activities and land-use authorizations and ensure compliance with pollution laws such as the Clean Air Act. The BLM must therefore obtain, collect, and analyze air-resource-related information to (1) determine baseline conditions of air and atmospheric values on the public lands; (2) evaluate changes in baseline conditions (trends); (3) understand the extent to which other natural resources (vegetation, hydrology, wildlife, range, minerals, etc.) are influenced by atmospheric conditions so that informed management decisions can be made; and (4) to assist in developing models to predict future conditions; such as, atmospheric dispersion models to assess air quality impacts. The BLM obtains information of acceptable quality collected from existing monitoring networks operated by other agencies and programs whenever possible to promote efficiency and avoid duplication of efforts. Examples of these networks include the National Weather Service Cooperative Observer Network, Natural Resources Conservation Service (NRCS) SNOTEL and SCAN networks, the National Interagency Fire Center Remote Automated Weather Station (RAWS) network, the Bureau of Reclamation Agricultural Weather (AgriMet) networks, the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network, the National Atmospheric Deposition Program (NADP), U.S. Geological Survey National Streamflow Information Program (NSIP), and individual state climate offices.

A Remote Automated Weather Station

When existing monitoring networks are not sufficient to meet the needs for air-resource- related information, the BLM initiates efforts to collect additional data through cooperative efforts with other agencies or with resource management staff in state and field offices. The BLM will expend an estimated total of $1,475,000 on such efforts in FY 2010. This total includes $121,000 to operate a series of RAWS stations equipped with additional instruments to measure soil moisture and winter precipitation not required for fire monitoring, and $110,000 to upgrade satellite communications modules; $222,000 to establish eight new stations in the NRCS SCAN network; $62,000 to operate six NADP sites; $100,000 on other efforts such as downscaling climate models and using wildlife water guzzlers to measure precipitation in remote catchments; and $860,000 for labor and logistics to support climate and weather data collection efforts by BLM resource management staff.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

USDA

The USDA National Institute of Food and Agriculture (NIFA)—the former Cooperative State Research, Education, and Extension Service—was created by Congress through the Food, Conservation, and Energy Act of 2008. NIFA's unique mission is to advance knowledge for agriculture, the environment, human health and well-being, and communities by supporting research, education, and extension programs in the Land-Grant University System and other partner organizations. NIFA doesn't perform actual research, education, and extension, but rather helps fund it at the state and local level and provides program leadership in these areas.

The Agriculture and Food Research Initiative (AFRI) is NIFA's flagship competitive grant program. AFRI has funded projects on a wide variety of weather- and climate-related research in collaboration with other U.S. Federal agencies. AFRI's Climate Change Challenge Area is currently focused on the following research areas: regional climate studies in agriculture and forestry, plant breeding, animal health impacts, and mitigation and adaptation in agriculture and forestry. Other AFRI areas of research related to weather and climate change include organic agriculture, carbon cycling, agro-ecosystem modeling, and economic consequences of adaptation and mitigation strategies. Emerging areas of research include the impact of climate on biofuel production, carbon cap-and-trade, and environmental markets.

Weather and climate research is conducted by USDA's Agricultural Research Service (ARS) across many different programs. Patterns of temperature, precipitation, and wind are important elements of risk management systems, ranging from crop and animal production to erosion

prediction. Climate change research is conducted from the perspectives of mitigation of the impacts of climate change on agriculture, and from the perspective of adapting agricultural systems for resilience to the impacts of changing climate.

ARS scientists are developing genetic resources to adapt crop production to increased drought, flooding, high temperature conditions, and wide swings of temperature over short periods of time. This effort includes the development of new varieties that will reduce susceptibility to losses from insect and disease that are exacerbated by the impacts of changing climate on habitats. New rangeland management systems are being developed to incorporate drought, higher temperatures and changes of snowpack into decision-making. New animal production systems are being developed to compensate for higher air temperature and humidity effects impacting animal health. ARS scientists also conduct research to understand and manage emissions of particulate matter, volatile organic compounds, greenhouse gases, and other materials from agricultural systems that affect air quality. Further, research to mitigate the effects of ozone on crop production is conducted. Identification, development, and distribution of genetic material that offers resistance to ozone damage is continuing.

ARS is working with scientists at NOAA, NASA, OCE/WAOB/JAWF, and land grant universities to improve observations, prediction, and impact assessments of drought across the U.S. A satellite data-based algorithm developed by ARS for mapping drought that delivers daily updates to users via the internet is currently being tested for operational use in the U.S. by the National Integrated Drought Information System (NIDIS) and is being tested for application to parts of northern Africa. ARS scientists are also key contributors to the development of future soil-moisture mapping satellites under development by NASA and international collaborators.

New technologies to mitigate the impact of drought via more efficient water management strategies such as irrigation scheduling with thermal remote sensing information and the use of non-potable water ("grey-water") to augment irrigation water supplies during times of drought are being developed by ARS. Crop management strategies such as alternate tillage and residue management are being explored as means to conserve soil moisture.

Weather and climate information needed to develop strategies for reduction of soil loss and sedimentation of water bodies and for prediction of flooding occurrence are being investigated. A combined wind and water erosion model for nation-wide conservation management practice planning that incorporates an ARS-developed wind erosion model is being further developed and refined for operational use by NRCS.

The ARS experimental watershed program actively participates in the NWS effort to modernize the Cooperative Observer (COOP) Network to ensure information needs of agriculture are addressed by the national surface observation network. Data from the ARS experimental watershed program is being used in the development of weather generators needed for models used to simulate weather events for research and decision-support systems.

AVIATION SERVICES

For purposes of this *Federal Plan*, Aviation Services are those specialized meteorological services and facilities established to meet the requirements of general, commercial, and military aviation. Civil programs that are directly related to services solely for aviation and military programs in support of land-based aviation and medium- or long-range missile operations are included. Detailed aviation services/products for specific areas include, but are not limited to, ceiling and visibility, convective hazards, en route winds and temperatures, ground de-icing, in-flight icing, terminal winds and temperatures, turbulence, volcanic ash, and other airborne hazardous materials.

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

NOAA National Weather Service

NOAA is legislatively mandated by Title 49 of the U.S. Code to provide weather information to the FAA. NWS aviation weather projects support increasing and improving observation capabilities, forecast products and techniques, outreach and training, operational adaptation of applied research, and verification of forecast products. These projects have the goal of improving the safe and efficient flow of air traffic in the National Airspace System (NAS). In response to requirements of the international community and the FAA, aviation weather products issued by NWS span the globe.

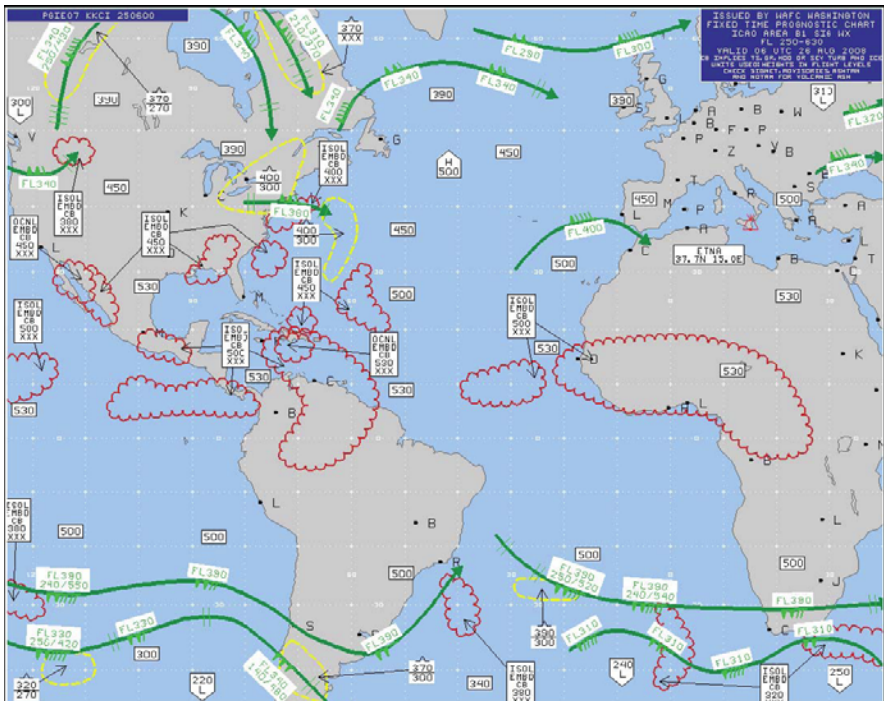
Under an international agreement through the International Civil Aviation Organization, the Aviation Weather Center (AWC), one of the NWS National Centers for Environmental Prediction (NCEP), is the mechanism by which the United States meets its weather forecasting obligations to the aviation community. 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, Atlantic, western portions of Europe, the Pacific, and Eastern Asia. The AWC, along with the Alaska Region's Alaska Aviation Weather Unit (AAWU), and the NWS Weather Forecast Office (WFO) in Honolulu, Hawaii, provides wind, temperature, and flight hazard (e.g., icing, and turbulence) forecasts for flight planning and en route aircraft operations for the United States, the north Atlantic and north Pacific routes, and some routes in the southern hemisphere.

Under an agreement with NOAA, NWS meteorologists are assigned to Center Weather Service Units (CWSUs) located in each of the 21 FAA Air Route Traffic Control Centers (ARTCCs). The CWSUs are currently supported by 84 NWS meteorologists (4 at each of the 21 ARTCCs) to provide real-time support and decision assistance concerning weather impacts on air traffic. In

addition to supporting the ARTCCs, the CWSUs provide meteorological support to en route centers, Terminal Radar Approach Control facilities, and airport towers.

The AWC also produces guidance products for use by WFOs in support of the airport terminal forecast function. To operationally support the needs of aviation users today, the NWS WFOs prepare Terminal Aerodrome Forecasts (TAFs) eight times a day, with amendments as needed, for more than 630 public-use airports in the United States and its territories in the Caribbean and Pacific. Thus, the AWC discharges large-scale, global aviation functions that can be sensibly centralized, while the WFOs discharge local aviation functions based on centralized guidance provided by the AWC. Additionally, NCEP's Environmental Modeling Center supplies global gridded model data of temperature, winds, and humidity twice daily for flight levels from 5,000 to 45,000 feet.

NWS's Aviation Weather Services Program funds a broad range of initiatives designed to improve the delivery of aviation weather information to 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 Services Program also serves as NOAA's focal point for development of NextGen (see "Research Programs and Projects," below).



The Aviation Weather Center (AWC) has the responsibility, as part of the World Area Forecast Center, Washington, to provide global weather forecasts of significant weather phenomena. Presently, the AWC produces these High Level Significant Weather charts covering two thirds of the globe, both northern and southern hemispheres that are issued four times per day.

Federal Aviation Administration

Weather is the single most disruptive factor affecting the NAS. Today's legacy meteorological assessment systems that support travel on the Nation's airways include the Advanced Weather Interactive Processing System (AWIPS); the Automated Surface Observing System (ASOS); the Weather and Radar Processor (WARP); the Weather Surveillance Radar-1988 Doppler (WSR-

8D), also known as the Next Generation Weather Radar (NEXRAD); the Terminal Doppler Weather Radar (TDWR); the Air Route Surveillance Radar (ARSR) systems ARSR-1, ARSR-2, ARSR-3, and ARSR-4; and the Air Surveillance Radar (ASR) systems ASR-8, ASR-9, and ASR-11. The objective of the FAA's Service Life Extension Program (SLEF) is to sustain these legacy systems until 2025, and the Joint Planning and Development Office (JPDO) is working to ensure that there is no interruption in service or significant degradation of mission capability from the current ground-based long-range radar systems until such time that the NextGen detection/surveillance system is operationally deployed.

Aviation Weather Observations, Levels of Service

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.

1. **ASOS Level D Service.** Level D Service is provided by a stand-alone ASOS. Level D service is available at 458 airports.
2. **ASOS Level C Service.** 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 300 airports.
3. **ASOS Level B Service.** 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 57 airports.
4. **ASOS Level A Service.** 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 69 airports.

The Automated Surface Weather Observation Network

The FAA's Automated Surface Weather Observation Network (ASWON) includes eight separate programs: (1) the Automated Weather Observing System (AWOS), (2) ASOS, (3) ASOS Pre-Planned Product Improvement (P3I) project, (4) Automated Weather Sensors Systems (AWSS), (5) Stand Alone Weather Sensors (SAWS), (6) AWOS Data Acquisition System (ADAS), (7) F-420 Wind System, and (8) Digital Altimeter Setting Indicator (DASI). ASWON provides automated surface weather observations to meet the needs of pilots, operators, and air traffic personnel. It supports the agency goal to Provide Weather Program Services, which includes objectives of maintaining current weather data collection, processing distribution capabilities, system capabilities, and interfaces, while conducting coordination with service units and external agencies to ensure weather information development efforts area consistent with the NextGen Concept of Operations.

AWOS provides basic aviation weather observations directly to pilots approaching the airport. The majority of these systems were installed at 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. 182 AWOSs are currently fielded.

ASOS. The ASOS program has been a joint effort of NWS, FAA, and the Department of Defense (DOD). The installed network of 884 ASOS sites nationwide serves as the primary surface weather observing network for the United States. ASOS is designed to support aviation operations directly, as well as providing basic weather observations for NWS forecast activities and for the meteorological, hydrological, and climatological research communities. About 426 ASOS are installed at towered airports where the FAA provides augmentation/backup of the observations. The remaining ASOS are installed at non-towered airports where the automated observation provides Service Level D weather reporting capabilities.

The NWS hourly wind fields, which are important to aviation users, are created by spatially and temporally interpolating wind forecast guidance from the latest run of the NWS's operational North American Mesoscale (NAM) weather forecast model with the ASOS data.

ASOS P3I. Whereas the other ASWON elements are all in service, this is the only remaining active program within the ASWON development portfolio. ASOS P3I consists of five efforts: (1) ASOS Processor Rehost, (2) Dewpoint Sensor Replacement, (3) Ice-Free Wind Sensor, (4) Enhanced Precipitation Identification (EPI) sensor, and (5) Ceilometer Replacement. Of these five, only the EPI sensor and Ceilometer Replacement remain in development. The ASOS P3I program is managed by the NWS under an interagency agreement.

AWSS. The AWSS has capabilities similar to ASOS. However, AWSS units were a direct FAA acquisition, rather than an acquisition through the joint ASOS program. The commissioning of the 19 AWSS was completed in 2005. Level C service is available at 7 airports and Level D service is available at 12 airports. An additional 25 AWSS units have been installed at airports in Alaska as part of the Automatic Dependent Surveillance-Broadcast (ADS-B)/Capstone program.

SAWS. This ASWON project was initiated in 1998 to provide temperature, dew point, wind speed and direction, and barometric pressure for altimeter settings. The systems were installed primarily as a back-up for AWSS/ASOS sensors at ASOS Level C airports where no other back-up capability is available. SAWS has also been certified for operational use and may, at the local Air Traffic Manager's discretion, be used to replace F-420 wind speed/direction indicators and DASI. SAWS capability has been demonstrated, production is complete, and the FAA has 131 SAWS systems installed and commissioned.

ADAS functions primarily as a message concentrator. It collects weather messages from AWOS, ASOS, and AWSS equipment located at controlled and noncontrolled airports within the area of responsibility of each ARTCC. ADAS distributes 1-minute AWOS/ASOS observations to WARP and to the Integrated Terminal Weather System (ITWS). ADAS forwards the AWOS/ASOS METAR, and SPECI observations to the Weather Message Switching Center Replacement (WMSCR) for further distribution. Field implementation of ADAS is complete, and a technology refresh effort is underway that will replace the ADAS in 2010-11.

AWOS for Non-Federal Applications

Under the Airport Improvement Program, State and local jurisdictions may justify to the FAA the 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 funding assistance under the program. Airports can also use State, local, or private funds to purchase a non-Federal AWOS. 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 1,085 non-Federal AWOS locations. Non-Federal AWOS may be AWOS-A, AWOS-A/V, or AWOS I, II, III or IV. Some of these, including AWOS III and AWOS IV, 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 (NG RVR) System

The NG RVR system provides RVR information to controllers and users in support of precision landing and take-off operations. This element of the NAS infrastructure incorporates state-of-the-art sensor technology and embedded remote maintenance monitoring. It provides near real-time measurement of visibility conditions along a runway (up to three points along the runway can be measured: touchdown, midpoint, and rollout). The system automatically collects and formats data from three sensors. 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. Forward-scatter meters will replace the transmissometers currently in use. The data processing unit calculates runway visibility products and distributes the products to controllers and other users.

Delivery of NG RVR visibility sensors began in November 1998. To date, 242 NG RVR systems are operating in the NAS. At the current annual levels of funding and deployment, the FAA plans to complete delivery of all NG RVR systems by FY2010. The program goal is to replace all remaining RVV, Tasker 400 and Tasker 500 systems. At present, 36 of these older systems continue to operate in the NAS. At the current rate of 10 installations a year, the FAA plans to have these systems replaced by 2012.

Personal Computer Based Runway Visual Range (PC RVR) System

In December 2009, the FAA began deploying the PC RVR system into the NAS. The PC RVR provides increased RVR capabilities at additional airports while also replacing the remaining Tasker and earliest deployed NG RVR systems.

Weather Camera Program

The FAA has installed Aviation Weather Cameras as an aid to Visual Flight Rules 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 over 100 camera sites installed and operating, with an additional 24 requested for FY 2011.

Low Level Windshear Alert System (LLWAS)

To help protect aircraft from catastrophic wind shear, the FAA uses a network of sensors collectively called the Low-Level Windshear Alert System. The LLWAS has undergone several advances in both design and computational algorithms over the program's life. The latest deployment, known as the LLWAS Phase III, adds sensors to the original LLWAS network, providing better coverage of the airfield. In addition, the LLWAS Phase III is capable of providing runway-oriented windshear and microburst alerts with loss and gain values. The LLWAS Phase III comprises hardware and software necessary to provide continuous real-time collection and analysis of wind data at and around an airport. It provides airport and runway wind speed and direction information and determines whether conditions exist that exhibit wind shear and/or microburst activity. If these conditions exist, the LLWAS produces alerts sent to Ribbon Display Terminals in the Air Traffic Control Tower and to Terminal Radar Approach Control. The system can support up to eight physical runways in all functions relating to wind analysis and runway-oriented messages and data.

With one exception, the LLWAS provides information on hazardous wind shear events that create unsafe conditions for aircraft landing and take-off at selected airports without TDWR coverage. The exception is that high-performance LLWAS-NE (network expansion) systems supplement the microburst detection capabilities of the TDWRs at nine airports.

The alerts from LLWAS-NE++ (FA-10387) will be integrated with alerts from the TDWR and the ITWS at most LLWAS NE++ locations. The LLWAS Relocation/Sustainment ((LLWAS-RS (FA-14100)) provides the same functionality and interfaces.

Terminal Doppler Weather Radar

The TDWR program consists of operational, dedicated aviation terminal weather radars based on Doppler techniques to detect wind and other weather conditions. TDWR units have been located to optimize the detection of microbursts and wind shear at selected airports with high operations and frequent weather impacts. Microbursts, which consist of an intense downdraft with strong surface wind outflows, are particularly dangerous to landing or departing aircraft. The radars are located near airport operating areas so as to provide the best scan of runways and the approach and departure corridors. The TDWR scanning strategy is optimized for microburst/wind shear detection. In addition, TDWR has the capability to identify areas of precipitation and the locations of thunderstorms. The FAA has 45 operational and 2 support TDWR systems. System displays are located in airport towers and at Terminal Radar Approach Control facilities.

A Terminal Doppler Weather Radar

The TDWRs provide wind shear alert conditions for airport approach and departure advisories. In addition, they provide supplementary wind information that allows airport managers to turn the airports around in time to accommodate wind shifts predicted by the TDWRs. This increases airport capacities by reducing the delays traditionally associated with major wind shifts. The high-performance LLWAS-NE (network expansion) systems supplement the microburst detection capabilities of the TDWRs at nine airports.

TDWR supports the agency goal of Provide Weather Products: Provide program management for capital acquisitions aimed at increasing safety. A service life extension program is underway to maintain and improve TDWR system capability. FAA investments for FY 2011 include the TDWR service life extension program.

Juneau Airport Wind System (JAWS)

The JAWS provides terrain-induced wind and turbulence data important to safety of flight and decreases the probability of experiencing unnecessary weather-related delays in and out of Juneau International Airport, Alaska. JAWS data are provided to the aviation community as advisory because of the restrictive geographical features that affect approach and departure paths. The JAWS measures and displays wind information to the Juneau Automated Flight Service Station for use in preparing pilot briefings. Alaska Airlines uses JAWS data to comply with its Operations Specification. The NWS uses JAWS data for weather forecasting, and other Alaskan aviation users access JAWS data via the Internet. JAWS supports the agency goal to Provide Weather Products: Provide program management for capital acquisitions aimed at increasing safety.

The National Center for Atmospheric Research (NCAR) developed the prototype JAWS and has been operating and maintaining it since 1998. A December 2008 investment decision approved implementing a hardened prototype as the end-state JAWS, which will be operated and maintained by the FAA. NCAR will provide operations and maintenance history and technical support during the transition to the end-state JAWS, which is planned for completion in early 2012. The investments for FY 2011 include JAWS-Hardened Prototype and Implementation.

Air Route Surveillance Radar

The ARSR-4 provides the ARTCCs with accurate multiple weather levels out to 250 nautical miles. The ARSR-4, which resulted from a project jointly funded by the FAA and the U.S. Air Force, greatly enhanced the ability to accurately report aircraft targets in weather for primary en

route radar. The ARSR-4 can provide weather information to supplement other sources. Forty-one ARSR-4 joint radar sites were installed from 1993 to 1998.

Weather Systems Processor (WSP)

The WSP program provides an additional radar channel for processing weather returns and de-aliasing returns from the other weather channel in the ASR-9 surveillance radar. 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 planned for installation are in place and operating, with an additional 5 support units. A technology refresh program to refurbish and restock system parts to extend system operability was completed in 2009.

Next Generation Weather Radar

Known operationally as the Weather Surveillance Radar-1988 Doppler (WSR-88D), NEXRAD 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. The other 149 WSR-88Ds, sponsored by NOAA/NWS and DOD, provide coverage for the continental United States.

The three NEXRAD funding agencies jointly support the field sites through the WSR-88D Radar Operations Center at Norman, Oklahoma. This center provides software maintenance, operational troubleshooting, configuration control, and training.

During WSR-88D development, the FAA emphasized the need for algorithms that take advantage of this radar's 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.

NEXRAD supports the agency goal of providing program management for capital acquisitions aimed at increasing safety. 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 in-flight icing and turbulence. FAA investments in NEXRAD for FY 2011 include NEXRAD Legacy, Icing, and Hail Algorithms.

Turbulence Nowcasts and Forecasts

FAA has had a research program focused on producing a system for real-time turbulence nowcasts and probabilistic forecasts of turbulence. The approach taken to meet these objectives includes a turbulence forecasting task in conjunction with two supporting sensor tasks: one for in situ detection of turbulence and the second for remote sensing of turbulence. The in situ task has resulted in the deployment of an aircraft-based turbulence detection algorithm on aircraft at

United Airlines and Delta Airlines. Current efforts include deployment at Southwest Airlines. 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 WSR-88D installations, will be used as input in the production of the Graphical Turbulence Guidance Nowcast (GTGN) product.

Turbulence forecast research efforts to date have resulted in the Graphical Turbulence Guidance Version 2 (GTG2), the current operational version, which provides deterministic clear-air turbulence forecasts from 0 to 12 hours for altitudes from 10,000 ft to Flight Level 450. GTG2 incorporates in situ turbulence observations. The next version, GTG3, will include forecasts for mountain wave turbulence and extend the forecasts to cover the period from 0 to 18 hours. GTG3 will use the Weather Research and Forecasting (WRF) Rapid Refresh model as input. Future versions of the Graphical Turbulence Guidance will be expanded to include all flight levels, provide global coverage, include convective turbulence forecasts, and provide probabilistic guidance, rather than the deterministic output from the current version.

Weather and Radar Processor

The WARP system was designed to close the performance gap of providing accurate and timely weather information by replacing weather data from the long-range surveillance radars with more accurate information from the NEXRAD system. It is operational at the 21 ARTCCs and at the Air Traffic Control System Command Center (ATCSCC). There are six primary WARP functions: (1) integrate timely and accurate weather onto air traffic controller displays; (2) support the Traffic Management Unit and to air traffic control specialists at the ARTCCs and the ATCSCC; (3) disseminate weather data to critical NAS subsystems; (4) provide current and forecast data to NWS CWSU meteorologists, who support air traffic personnel; (5) present accurate weather information in an integrated manner in the en route environment to give air traffic controllers a comprehensive picture of where aircraft can safely fly, while making the most efficient use of airspace.

The WARP system will continue to be sustained until the equivalent functionality in the NextGen Weather Portfolio is deployed. A WARP technical refresh is addressing the aging infrastructure of the existing hardware and software systems. These activities include communications upgrades, implementation of mandatory security certification and accreditation package (SCAP) mitigation activities, and the design and development of interfaces to critical NAS systems that require weather data such as the En Route Automation Modernization and Advanced Technologies and Oceanic Procedures systems. For FY 2011, maintenance and sustainment activities will continue, including ongoing required information systems security activities. Efforts will be initiated to incorporate data format changes.

WARP continues to support the FAA's Strategic Flight Plan goal of Greater Capacity: Work with local governments and airspace users to provide increased capacity in the NAS that reduces congestion and meets projected demand in an environmentally sound manner. The WARP system also enhances safety, reduces weather-related delays, and improves collaborative decisionmaking.

Wind Shear Detection Services (WSDS)

WSDS is a portfolio of ground-based wind shear technologies in the NAS. It consists of two work packages (WP). WP1 (Legacy) contains LLWAS, WSP, and TDWR. These legacy wind shear technologies are nearing the end of their life expectancy, and for this reason, they are in desperate need of a service life extension program or technology refresh until the NextGen replacement technology is available. WP2 consists of new wind shear technology such as Wind Hazard Detection Equipment (WHDE, formally LIDAR), and the expansion of wind shear service to unprotected and underprotected sites.

The business case to be developed for WSDS will evaluate all of these systems together to determine how to maintain existing wind shear service while modernizing, improving, and right-sizing the component capabilities across the service. The output of this business case will be recommendations on how to sustain existing wind shear service, while improving wind shear system performance in a cost-effective and efficient manner.

WSDS supports the agency goal of Provide Weather Products: Provide program management for capital acquisitions aimed at increasing safety. The investments for FY 2011 include WSDS Work Package 1.

Integrated Terminal Weather System (ITWS)

The FAA developed ITWS to provide new technology to help air traffic flow more efficiently during periods of bad weather. The ITWS receives and integrates weather data from a number of FAA and NWS radars and sensors. It uses highly sophisticated meteorological algorithms to display current and predicted weather and warnings of potentially hazardous weather events from the airport out to 200 nautical miles. ITWS provides accurate, easy-to-understand, and immediately usable weather information on full-color graphic displays.

ITWS uses data from AWOS, ASOS, LLWAS, TDWR, and NEXRAD Models 9 and 11. Other inputs include the National Lightning Detection Network, data from the NWS Rapid Update Cycle forecast model, and the Meteorological Data Collection and Reporting System. ITWS products include such weather information as windshears, microbursts, gust fronts, storm cell motion and speed, terminal area winds aloft, lightning, hail, and tornadoes. A Terminal Convective Weather Forecast enhancement was added in 2006 to increase the forecast time of the predictive products from 20 to 60 minutes. This enhancement provides additional data to assist air traffic personnel in using forecast information more effectively.

ITWS displays are located in air traffic control towers, terminal radar approach control facilities, and ARTCCs. Intranet web-based ITWS products are available to the ATCSCC, airline operations centers, and other approved users. Pilots can also receive ITWS information in the cockpit. Via an intra-agency agreement, the John A. Volpe National Transportation Systems Center (Volpe Center) hosts the ITWS User II Web Site, which distributes ITWS data to external users. The availability of this enhanced weather information means that system users now will be able to employ these products in their flight planning and that FAA will be better equipped to manage the nation’s air traffic.

FAA traffic managers and controllers, the airlines, pilots, and other airspace users can use ITWS information to improve the efficiency and safety of air traffic flow during bad weather. ITWS provides the benefits of common situational awareness, collaborative decisionmaking, and tactical planning for its users. For example, the current and future predicted locations of weather around airports, which affects both airborne and ground operations, can be used to keep runways open longer as hazardous weather approaches and reopen runways sooner after the hazard passes, allowing more takeoffs and landings. These efficiencies increase capacity and reduce weather delays for airlines and the traveling public, saving time for the flying public and money for the airlines. FAA benefits studies have shown that ITWS is generating significant benefits for the FAA and airlines.

The FAA and Massachusetts Institute of Technology Lincoln Laboratory installed prototype versions of ITWS at four airports between 1993 and 1998. Based on the success of the prototypes, the FAA competitively selected the Raytheon Company to develop and deploy 33 production ITWS systems. The first fully operational ITWS site was commissioned at Kansas City International Airport on April 10, 2003.

As of February 2010, the FAA has installed and commissioned ITWS at 32 operational sites serving 51 airports, 28 of which are Operational Evolution Partnership (OEP) Level 1 airports. Two other systems, serving 8 airports (including one OEP airport), became operational in 2010. Four support systems have also been installed. ITWS Situation Displays will be installed in 15 Secondary Reliever airports starting in 2010, and installations will continue in 2011. On July 27, 2009, ITWS received Joint Resource Council approval for a replan to add another site to its program. The addition is at the Northern California Terminal Radar Approach Control facility and includes tower facilities at Oakland, Reno, Sacramento, San Francisco, and San Jose. In all, 74 airports will be served by ITWS when currently planned installations are completed.

ITWS continues to support the FAA's Strategic Flight Plan goal of Greater Capacity: Work with local governments and airspace users to provide increased capacity in the NAS, thereby reducing congestion. ITWS meets projected demand in an environmentally sound manner. On February 18, 2010, ITWS successfully completed a Post Implementation Review conducted by the FAA Joint Resources Council Investment Process Management Group, which concluded that:

- ITWS achieved all of its performance goals, as documented in the Office of Management and Budget (OMB) Exhibit 300 FY 2011 submission.
- The original ITWS business case, which defines ITWS functionality, cost, and benefits, continues to be valid.

Operational and Supportability Implementation System (OASIS)

The FAA acquired OASIS to integrate graphics weather products, flight planning, aeronautical data processing, and timeliness of data dissemination for Flight Service operations, thereby enhancing the safety and efficiency of the NAS. OASIS replaced the outdated Model-1 Full Capacity Flight Service Automation System and legacy graphic weather display systems. It incorporates automated flight service data handling capabilities that provide flight planning, weather briefings, Notices to Airmen (NOTAMs), special use airspace, and search and rescue services. OASIS systems in the continental United States were de-installed in 2007, but OASIS

systems are currently operational at the FAA's 14 Flight Service Stations and 3 Automated Flight Service Stations in Alaska. OASIS will continue to operate in Alaska until replaced by the Meteorological and Aeronautical Planning System (MAPS).

Terminal Weather Information for Pilots (TWIP) Program

The TWIP program provides text message descriptions and character graphic depiction of potentially hazardous weather conditions in the terminal area of airports. TWIP 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 functionality was initially incorporated in the TDWR software and deployed at 47 commissioned TDWR sites. Following the installation of ITWS at the TDWR sites, TWIP weather data is now provided as an output product of ITWS. Thirty-one of the 33 ITWS sites were commissioned as of the end of FY 2009, with the remaining two systems scheduled for installation in FY 2010. TWIP weather data are also available as an output product from the 34 commissioned WSP sites, but availability depends on National Airspace Data Interchange Network (NADIN) II connectivity and program funding.

Direct User Access Terminal (DUAT)

The DUAT system has been operational since February 1990. DUAT is an Internet capability through which pilots are able to access weather and NOTAMs, as well as file their Instrument Flight Rules and/or Visual Flight Rules flight plans from their home or office personal computer.

Aviation Weather Communications

FAA Wide Area Networks (WANs) provide communications for all operational NAS systems and services. Weather data, products, and information constitute a large percentage of network traffic, as do NOTAMS, flight planning, flight movement, and other aeronautical data. The FAA Telecommunications Infrastructure (FTI) network is rapidly replacing legacy NAS network services because of its ability to provide contemporary protocols, enhanced security services, user specific service availability, and increased operational bandwidth for both present and future NAS users/systems. Legacy network users, such as those utilizing the NADIN Packet-Switched Network (PSN) (also called NADIN II) are being migrated to FTI for network service. This change is largely due to obsolescence and supportability issues with the legacy NADIN II network, which is scheduled to be decommissioned by December 2010.

The NADIN II PSN was commissioned in 1995 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 meshed backbone network that provides high availability of services, at low to medium speeds, to the network's users. NADIN II consists of operational nodes at all ARTCCs and at the two network control centers at the Network Enterprise Management Center (NEMC) facilities at Salt Lake City, Utah, and Atlanta, Georgia. NADIN II presently provides network services to WMSCR, WARP, ADAS, TMS, the Consolidated NOTAM System, and a number of other nodes in the aviation weather information system serving NAS users.

Weather Message Switching Center Replacement

The WMSCR system, which is housed in the NEMC facilities, replaced the Weather Message Switching Center located at FAA's National Communications Center (NATCOM), Kansas City, Missouri, with technology that was the state of the art when it was commissoned in 1995. 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 for NAS users. It collects, processes, and stores aviation weather products and disseminates them to major NAS systems, the airlines, and international and commercial users. WMSCR also provides storage and distribution of domestic NOTAMs and retrieval of international NOTAMs through the Consolidated NOTAM System.

The WMSCR system operates in a Primary/Backup mode via geographically redundant systems at the NEMC facilities in Atlanta and Salt Lake City. Replication occurs between the redundant systems at the NEMC facilities to ensure database information is identical. In the event of a failure of the primary system, the surviving node assumes responsibility for collection and distribution of data for the entire NAS network user community.

The WMSCR system has undergone a number of technology refreshes to ensure continued supportability and maintainability. Currently, the system software is being modified to incorporate a subset of System Wide Information Management (SWIM) products (See discussion below under NextGen programs.) The system hardware is due for technology refresh in 2011. Plans are presently underway for migration of the system to a common hardware platform with other like system functionality to reduce the number of disparate platforms and ensure supportability. It is expected that WMSCR functionality will eventually be subsumed into SWIM.

World Area Forecast System (WAFS)

The WAFS, which is compliant with ICAO Annex 3, produces flight planning products used in international air carrier operations. It incorporates product generation and satellite distribution functions. The data available via WAFS include flight winds, observations, forecasts, SIGMETs, AIRMETs, and hazards to aviation including volcanic ash clouds. The information and products are prepared at two World Area Forecast Centers (WAFCs) designated as WAFC Washington, and WAFC London.

Distribution is accomplished through four geosynchronous satellite broadcasts operated by the two WAFCs. Three of the four satellites are funded by the United States. The first is located over the western Atlantic with a footprint covering western Europe and Africa, the Atlantic Ocean, South America, and North America (except for the West Coast and Alaska). The second U.S.-funded satellite is positioned over the Pacific and covers the U.S. West Coast and Alaska, the Pacific Ocean, and the Pacific rim of Asia. The third U.S.-funded satellite is positioned over the Indian Ocean and primarily covers East Asia. A fourth satellite, operated by the United Kingdom, is stationed over the western Indian Ocean and covers the remaining areas of Europe, Asia, and Africa.

National Volcanic Ash Operating Plan for Aviation

Under the auspices of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), the following agencies participate in the interagency Working Group for Volcanic Ash (WG/VA) and Committee for Aviation Services and Research (CASR): FAA, NOAA, U.S. Air Force, and U.S. Geological Survey (USGS). Through its Volcanic Hazards Program, the USGS is responsible for monitoring volcanoes in the United States and issuing eruption forecasts and notifications. The WG/VA 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 erupted into the atmosphere.

Volcanic ash hazards can be catastrophic to aviation operations.

There are regional plans in addition to the national plan. The Regional Interagency Volcanic Ash Operating Plan for Alaska was updated in 2010 and the plan for the Pacific Northwest is expected to be completed in 2011. Regional plans typically also involve state and local agencies.

Because of the proximity of Aleutian volcanoes to busy North Pacific air routes, the USGS's Alaska Volcano Observatory (AVO) has been and continues to be a world leader in the integration of volcano observatory operations with efforts to mitigate the risk from airborne volcanic ash to en route aircraft. AVO monitors continuous real-time data from seismic networks at approximately 33 volcanoes in the Aleutian Islands. It also uses data from various satellites to assess activity and track airborne ash. Data and information from AVO monitoring activities are supplied to FAA and DOD to provide warnings for pilots and aircraft operators in the Alaskan region and to NOAA/NWS to aid in its forecasting and tracking of ash clouds. USGS also monitors activity in the Northern Mariana Islands and has an interagency plan for that area. There is frequent activity in the Marianas; the most recent significant eruption occurred in May 2010 when an underwater seamount erupted, sending ash to more than 40,000 ft.

The eruption of Eyjafjallajökull in Iceland in the spring of 2010 and ensuing shutdown of European airspace focused attention on the global economic disruption that a volcanic ash cloud can have on the transportation of people and goods. USGS experts on the issue of airborne volcanic ash have been working with FAA, NOAA, and DOD colleagues to improve capabilities in mitigating the impact of the presence of volcanic ash in busy flight routes, both domestic and international. In response to t—he heightened interest, USGS established a new project that

focuses exclusively on volcanic ash and brings together existing USGS efforts in research, development of new operational tools, and assisting policy makers.

Recognizing that many potentially dangerous volcanoes have inadequate or no ground-based monitoring, the USGS recently evaluated 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 air-traffic corridors require sufficient monitoring capability with ground-based instruments to detect and track unrest in real-time so that other agencies responsible for en route 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.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NextGen: For the NAS of the Future

To address the growing demands on the NAS for the future, the 108th Congress and the George W. Bush Administration promulgated and signed into law the VISION 100 Act—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. The Vision 100 Act directs the Department of Transportation, FAA, Department of Commerce, National Aeronautics and Space Administration (NASA), and the JPDO to conduct integrated planning for research to operations to support the multi-agency NextGen system.

Along with the private sector and academic community, the FAA, 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 JPDO, which reports to the Senior Vice President for NextGen and Operations Planning within FAA's Air Traffic Organization (ATO). Within JPDO is the Weather Working Group (WWG), which facilitates integrating longer-term planning.

Collectively the effect of the NextGen R&D portfolio will result in aviation weather data no longer being just a stand-alone display, requiring cognitive interpretation and impact assessment, with limited ability to significantly reduce weather-related delays. Instead, weather information is being designed to integrate with and support NextGen's decision-oriented automation capabilities and human decisionmaking processes.

The programs in progress to develop tomorrow's aviation weather systems to support NextGen capabilities include the NextGen Network Enabled Weather (NNEW) and the Reduced Weather Impact (RWI) programs. Research efforts are underway to demonstrate and evaluate the ability to integrate weather information from multiple Federal agencies through the use of an electronic catalog of aviation weather data. The goal is to establish weather-specific services design standards and weather data format standards to enable the operational delivery of six data sets through network-enabled mechanisms by 2014 and the dissemination of four-dimensional (4-D) Weather Data Cube capabilities.

NextGen Integration and Implementation Office

Within the FAA/ATO, two principal entities that report to ATO's Senior Vice President for NextGen and Operations Planning are focused on implementation of NextGen, especially in the near and medium term: the NextGen Integration and Implementation Office and the Aviation Weather Group (AWG). 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. These sets include the NNEW and the RWI Solution Sets, which are focused on improving weather observations, weather forecasts, and operational decisions by integrating weather information.

AWG and Aviation Weather Services Directorate Roles in NextGen Transition

The Aviation Weather Services Directorate (AWSD) within FAA/ATO and the AWG have important roles in the transition from today's aviation weather services to future NNEW, RWI Weather Forecast Improvements, and other NextGen Weather Processing capabilities, as the FAA moves from air traffic *control* to air traffic *management* (ATM). In the NextGen system, most communications will occur as digital data, much of it transferred directly from computer to computer. Relevant information will be shared easily among system users through network-enabled information access.

One of the primary functions of the FAA ATO is development and management of requirements for the FAA Capital Investment Plan. Within the ATO, the AWG and the Operations Planning Service component co-manage 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. This program develops strategic plans and defines weather-related 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.

NNEW and the 4D Weather Data Cube

NNEW is a key FAA contribution to an interagency effort to provide quick, easy, and cost-effective access to weather information. It will serve as the infrastructure core of NextGen aviation weather support services and provide access to a common weather picture across the national airspace system. NNEW is one of five NextGen Transformational Programs that will provide universal access to weather information, thereby enabling collaborative and dynamic NAS decisionmaking. In addition, the NNEW transformational program will address the weather dissemination infrastructure within the FAA.

NNEW will identify, adapt, and utilize standards for system-wide weather data formatting and access. Using network-enabled operation capabilities, aviation weather information from multi-agency sources will be developed that can be directly and commonly accessed by and integrated into user decision support tools. The virtual database will consolidate a vast array of ground-, airborne-, and space-based weather observations and forecasts, updated as needed in real time, into a single, national, eventually global, picture of the atmosphere.

NNEW will define and provide the FAA's portion of the interagency infrastructure known as the Four-Dimensional Weather Data Cube (4D Wx Data Cube). The 4-D Wx Data Cube will provide common, universal access to aviation weather data. All categories of weather users will have improved access to timely and accurate weather information to support improved decisionmaking, while enhancing safety. The 4D Wx Data Cube will consist of (1) weather data published in various databases within FAA, NOAA, and DOD, as well as commercial weather data providers that may participate; (2) registries/repositories needed to locate and retrieve published data; (3) the capability to translate among various standards that will be employed provide data in user required units and coordinate systems; and (4) the capability to support retrieval requests for selected data volumes (such as weather conditions along a flight trajectory). A subset of the data published to the 4D Wx Data Cube will be designated as the Single Authoritative Source (SAS). The SAS identifies the preferred data that should be used to support collaborative ATM decisions and ensure that such decisions are based on consistent data.

The 4D Weather SAS will be an optimal representation of all Air Navigation Service Provider (ANSP) weather state information that is used directly or translated into operational impact by the ANSP and that is consistent in time, space, and among weather elements. The 4D Wx SAS will be specified by the ANSP and accessible to all users of the NAS. It will be the source of weather information for ANSP's ATM decisions and will be supported by the same network services as the 4D Wx Data Cube.

The ANSP will specify characteristics of weather state information needed to support its ATM decisionmaking and the corresponding decision support tools. As NextGen capabilities mature, the ANSP requirements will evolve. The NWS will, in coordination with Air Force and Navy weather services, determine what weather state information best meets the 4D Wx SAS requirements specified by the ANSP; information from any source, including commercial sources, can be used to meet SAS requirements as long as it can be freely distributed to all NNEW users.

With rare exceptions, the 4D Wx SAS will be the only source of weather information for the ANSP's ATM decisions; however, it will not necessarily be the only source for other decisionmakers, such as pilots, dispatchers, and military operators. Making the 4D Wx SAS both a support tool for the ANSP's ATM decisions and a NextGen resource provides transparency and predictability in these decisions and a shared situational awareness for all NextGen participants.

NOAA's role in the 4D Wx Data Cube

NextGen was established by Congress to transform the NAS and accommodate the projected tripling of demand for air transportation. The NextGen plan will increase NAS capacity by utilizing highly automated systems to manage 4D aircraft trajectories 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 information. This 4D Wx Data Cube, which NOAA is developing in close coordination with the FAA, must be continuously updated and internally consistent. It will utilize Network Enabled Operations to provide for common situational awareness. The 4D Wx Data Cube will give NOAA the ability to provide NAS 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 2013.

The Reduced Weather Impact (RWI) Solution Set

RWI is a planning and development portfolio to ensure that NextGen operational weather capabilities utilize a broad range of weather improvements and technologies to mitigate the effects of weather in future NAS operations. It includes two programs: **Weather Observation Improvements** and **Weather Forecast Improvements**. RWI will also address integration of these improvements in weather observation quality and forecasting into user decision-support tools.

Working with the AWG, the development team for the RWI Solution Set coordinates the investment analysis and acquisition of new weather systems and services with the AWSD in FAA/ATO/System Operations Services, which is responsible for ATCSCC system operations. The ATCSCC monitors and analyzes system components and weather patterns for potential system impact.

RWI will address many weather hazard mitigation problems including, but not limited to, rightsizing the observations network, transition of weather research to operations, development of weather impact metrics, development of weather decision-support tools, integration of weather information into operations, weather processor architecture redesign and restructuring, and transition planning for legacy systems. RWI will conduct planning, prototyping, demonstrations, engineering evaluation, and investment readiness activities, leading to an implementation of operational capabilities throughout NextGen in the near, mid, and far terms. RWI will propose recommendations for the near, mid, and far time frames; these will include recommendations for transition of FAA legacy systems.

A consistent and effective weather observation sensor network will be a cornerstone to improved NextGen weather capabilities. **RWI Weather Observation Improvements** will focus on

evaluating the current observation capability against that needed to support NextGen. This evaluation will include a gap analysis to determine the optimal quantity and quality of ground-, air-, and space-based sensors. The analysis will determine whether cost effective sensor densities and performance, redundancies, or inconsistencies impact aviation operations. Tasks to be performed include the evaluation of concepts for replacement of current weather radar with a single integrated radar technology or other new sensors.

The **RWI Weather Forecast Improvements** program addresses the need to enable better weather decisionmaking and use of weather information in the transformed NAS. This includes (1) integrating weather information tailored for decision-support tools and systems into NextGen operations, (2) implementing improved forecasts by transitioning advanced forecast capabilities from aviation weather research, (3) developing and using metrics to evaluate the effectiveness of weather improvements in the NAS, (4) developing probabilistic forecasts that can be used effectively in air traffic and traffic flow management, and (5) determining the most effective solution for a processor architecture to support these capabilities.

The acquisition strategy for the RWI Weather Forecast Improvements program will include implementing the NextGen Weather Processing capability by initiating migration of legacy capabilities to the new capability, transitioning advanced weather forecast applications into operations, evolving the NextGen Weather Processing architecture through continued migration of legacy capabilities, and continuing the transition of advanced forecast applications into operations.

Weather Technology in the Cockpit (WTIC) Program

One of the weather-related goals of NextGen is to reduce weather delays, allowing more efficient and flexible ATM. The objective of the WTIC Program is to meet minimum standards for flight deck weather information and communications management—while also meeting human factors requirements—that will provide flight crews with timely, comprehensive weather information from onboard sensors, crosslink communications from nearby aircraft, and uplink from ground-based processors to support flight replanning and weather hazard avoidance in flight. WTIC also includes airborne sensor observations of nearby aircraft for weather avoidance decisions and ground-based processors for direct and forecast use in ATM decision-support processes.

To derive WTIC functional and performance requirements, initial research under the program will evaluate the overarching NextGen Concept of Operations (ConOps) and requirements for NextGen weather support on the flight deck. WTIC will then develop and execute a research program plan that includes identifying any current capabilities that meet the NextGen requirements; evaluating planned and funded development of new weather support capabilities; identifying gaps between NextGen requirements and current developing weather support capabilities; and allocating such capability gaps to the commercial sector, government, or both for development of NextGen Solution Sets.

The WTIC program will identify global data link requirements and standards for transporting meteorological information to and from the flight deck. Data links are required to support uplink, downlink, and crosslink advisory and safety-critical meteorological information to NAS users who come under the three FAA service categories (corresponding to Parts 91, 121, or 135 of the

Federal Aviation Regulations) and are operating in various coverage environments. Consequently, the WTIC program will define requirements and standards for bandwidth, security, quality of service, and reliability to the government- and nongovernment-operated datalinks, to implement NextGen meteorological data link information.

WTIC human factors research will enable development of human performance, technology design, and human-computer interaction capabilities sufficient to meet requirements and standards aimed at providing safe, efficient, and cost-effective operations and training for hazardous weather on the flight deck and on the ground. Although technologically advanced graphical weather information products have entered the general aviation (Part 91) market in the past decade, the percentage of accidents that the National Transportation Safety Board has attributed to weather factors or to weather-related pilot error has remained fairly stable. The human factors research under WTIC will attempt to identify shortcomings in current capabilities and areas to focus weather technology advances to optimize safety and efficiency for Part 91, 121, and 135 operators.

The information management and human factors research deliverables under the WTIC program will (1) enable the development of Air Circulars and Orders for NextGen training, symbology, and information standards and (2) support development of aircraft certifications standards for Minimum Aviation Safety Performance Standards (MASPS), Minimum Operations Standards (MOPS), and Technical Standard Orders (TSO) to support development, operations, and procedures for weather technologies in the cockpit. In addition, WTIC program research will support development of communications information management to meet the storage and retrieval requirements and standards of NextGen for acquiring meteorological information from commercial and government-provided graphical and textual databases.

For FY 2011, the WTIC program includes the following major activities and anticipated accomplishments:

- Develop mid-term ConOps and obtain partner, stakeholder, and user concurrence for weather technology in the cockpit based on foundational elements identified in the NextGen ConOps, including integration of weather-in-flight-deck decision-support tools, weather dissemination management, and general aviation (Part 91) operations
- Validate ARP 5740, Cockpit Display of Data Linked Weather Information
- Determine the incremental weather information needed in cockpit operations for flight replanning and en route avoidance maneuvers, decision support, and situational awareness for Part 121, 135, and 91 aviation operators
- Verify and validate datalink signal latency, bandwidth, and quality of service to disseminate icing and turbulence products to the flight deck within the NAS
- For Pacific Ocean transoceanic flights between California and Australia, demonstrate the utility of an in-flight display of uplinked satellite-based product that outlines the 30,000-ft. and 40,000-ft. convective cloud top heights in a 2-hour look-ahead display relative to aircraft position and flight direction

- Initiate demonstration and evaluation of the usefulness of uplinking turbulence eddy dissipation rates (EDR) to the flight deck for incorporation in aircrew mitigation procedures
- Equip selected aircraft with certified electronic flight bags to accomplish flight crew operational evaluations of convective oceanic cloud top flight, graphical turbulence, and icing
- In collaboration with NASA, investigate means for network-enabled airborne use of radar-derived weather data

System-Wide Information Management

SWIM is a new concept developed in conjunction with NextGen to support NAS operations starting in 2011 and eventually to support full deployment of NextGen. SWIM will provide corporate services, including the messaging structure, security aspects, and the FTI IT network, that are required for all NextGen Solution Sets. It thus provides the core services to move data around the network and to do information management and messaging. These connections will allow each processing node in the network to receive its intended raw data, process it, and make the processed output available to the 4-D Weather Data Cube again for integration into decision support tools and for viewing by end users.

The NextGen Solution Sets and the weather solution sets will interface to all the weather systems through the NNEW. NNEW will use the SWIM core services to provide access to all weather data resident in the 4D Wx Data Cube. Having this single authoritative data source will ensure that collaborative decisionmaking in ATM benefits from a common situational awareness of current and forecast weather conditions.

ITWS in NextGen

See ITWS current operational status above, in the section on "Operational Programs, Including Products and Services." ITWS is a "NextGen Contributor" program and directly supports the NNEW and RWI initiatives. On behalf of the FAA, via an Intra-Agency Agreement, the Volpe Center is leading the development effort for the Terminal Data Distribution System, hosting ITWS, and facilitating the exchange of critical flight information as part of the SWIM initiative. Using ITWS, the Volpe Center successfully developed and delivered the first SWIM-compliant weather data feed, enabling traffic managers to adjust flight patterns at ITWS-equipped airports to accommodate changes in weather conditions. This ITWS-SWIM prototype has been operational since the end of FY 2008. ITWS-SWIM Segment 1 operational capability is planned for FY 2011. ITWS-SWIM supports the FAA goal of Greater Capacity: Work with local governments and airspace users to provide increased capacity in the NAS that reduces congestion and meets projected demand in an environmentally sound manner.

Corridor Integrated Weather System (CIWS)

The CIWS is a fully automated weather analysis and forecasting system whose products provide airspace coverage over the continental United States and southern Canada. It combines data from U.S. and Canadian weather radars with satellite data, surface observations, and numerical weather models to produce automated high resolution 3D precipitation forecast products in the

tactical timeframe (zero to 2 hours in the future) with fast update rates. Studies have shown that CIWS provides significant savings in operational delays by keeping aviation routes open longer, re-opening weather-affected routes sooner, and re-routing aircraft around severe convective weather. CIWS thus helps to meet the Greater Capacity goals outlined in the FAA Flight Plan.

A Corridor Integrated Weather System Terminal

A CIWS prototype is operated for the FAA by MIT Lincoln Laboratory through an interagency agreement with the U.S. Air Force. This prototype, performing under a Test NAS Change Proposal provides a dedicated display of CIWS products to traffic managers, area supervisors, and meteorologists in eight ARTCCs, six Terminal Radar Approach Control Facilities, and the ATCSCC, as well as to personnel at participating airline operations centers. Users at other facilities have access to CIWS products via a web-based display on the Internet.

In addition to being provided via dedicated and web-based prototype displays, the prototype CIWS products are provided to integrated ATM decision support systems. A dissemination capability is being developed in conjunction with the SWIM Program to enable CIWS data to be available to external users for integration into their own tools. An initial prototype is planned for completion in FY 2010. CIWS product generation will continue until it is functionally replaced as part of the NextGen Weather Processor in the 2015 timeframe.

Meteorological and Aeronautical Planning System

MAPS, which represents the next generation of flight service automation systems, is designed to increase flight planning and weather briefing functionality for the general aviation (Part 91) community through the use of performance planning tools and decision support tools. When combined with a single pilot database, MAPS will provide a common picture of weather and aeronautical information, including local area knowledge, to pilots and flight service specialists. It will provide information updates on a subscription basis relevant to the flight and based upon previously delivered information. It will allow pilots both independent access and interactive briefings though an integrated web portal. MAPS will provide flight progress monitoring that will lead to expedited search and rescue capabilities, more streamlined communications between responsible organizations, and reduced search areas. Initial operational capability is planned for 2015.

FAA Aviation Weather Research Program (AWRP)

The goals of the AWRP are to provide timely and accurate deterministic and probabilistic aviation weather information. The AWRP sponsors applied research at National laboratories, Government agencies, and universities to minimize the impact of weather on the NAS. While this research is now primarily focused on supporting the NextGen weather operational improvements, it also supports the FAA Flight Plan goals of greater capacity and increased safety. FAA collaborations with the NWS and NASA increase the 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.

AWP activity in support of the 4D Wx SAS is included in the discussion above of NNEW and the 4D Weather Data Cube.

In-Flight Icing

This AWRP research is aimed at developing improvements to in-flight icing diagnosis, which includes detection and forecasting. The Current Icing Product and Forecast Icing Product have been developed to provide hourly updates of, respectively, current conditions and forecast conditions out to 12 hours. These products include severity and probability of icing conditions and potential for super-cooled large water-drop formation. Planned efforts include expanding both icing products to cover Alaska and global oceanic routes.

Convective Weather

AWRP efforts in convective weather are targeted to developing an advanced storm prediction algorithm over the continental United States to provide more accurate structure depiction (including growth and decay) with longer warning lead times for hazardous convection and winter storm activity. These improvements will enable ATM decisionmakers to make enhanced decisions relative to traffic flow and will improve aviation safety near thunderstorms. Fuzzy logic forecast technology, coupled with numerical weather prediction modeling and climatology, will be used to produce a blended forecast from 0 to 8 hours and beyond. These forecasts will enhance the capability to predict growth, real extent, and movement of convective storms, as well as type(s) of precipitation from them. Probabilistic forecasts are also being developed to enable more accurate traffic flow management decisions and more efficient use of the NAS.

Model Development and Enhancement

This AWRP 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. The development of the WRF modeling framework 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. A new higher-resolution (mesoscale) modeling system based on 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 Rapid Update Cycle 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. A WRF nonhydrostatic mesoscale model has been under development since 1998. A version of the WRF model was implemented within the North American Mesoscale (NAM) model application, and mature testing is now occurring for the WRF Rapid Refresh model (including a version of the WRF-ARW) to replace the current Rapid Update Cycle model.

National Ceiling and Visibility Products

The National Ceiling and Visibility (NCV) Product Development Team is developing automated ceiling and visibility products to support current needs and future NextGen requirements for improvements in general aviation (Part 91) safety and terminal area traffic flow efficiency. Current NCV work focuses on development of (a) a real-time deterministic nowcast presenting current ceiling, visibility and flight category fields (the NCV Nowcast, or NCVN) and (b) hourly-updated probabilistic forecasts, from 1 out to 12 hours in the future, of these same fields (the NCV Forecast, or NCVF).

The NCVN Continental United States product makes use of real-time METAR (Meteorological Terminal Aviation Routine Weather Report) observations and satellite data from Geostationary Operational Environmental Satellite (GOES)-East and GOES-West to produce its automated nowcast on the National Digital Forecast Database (NDFD) 5-km grid. Nearest neighbor interpolation is used to populate grid points between METAR sites. The product is updated every 5 minutes. Confidence values tailored to each field are produced to aid user interpretation. The product is available under the "METARS" tab on the Experimental Aviation Digital Data Service (ADDS) website, through the Experimental Helicopter Emergency Medical Service Low-Altitude Flight Tool on Experimental ADDS, and as a Gridded Binary Data (GRB2) file. Future work will develop NCVN capability for Alaska.

Volcanic Ash Dispersion Forecasts

AWRP efforts in this research area target the development of enhanced forecasts of volcanic ash transport and dispersion in support of FAA traffic flow management and airline operations centers for flight planning, as well as for issuing in-flight advisories to alert aircraft of potentially hazardous conditions. In addition, Volcanic Ash Advisory Centers and Meteorological Watch Offices will have this information available to support their efforts to provide improved and timely products that show the location of the ash cloud. Enhancements will come through evaluating the ash transport/dispersion model and developing and validating the current performance parameters and requirements for volcanic ash in the atmosphere. The output from requirements validation will be leveraged with other agencies to develop an ensemble modeling/forecast approach for improved volcanic ash dispersion forecasts for ATM.

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 research products into operations.

The Network-Enabled Verification Service (NEVS) is under development to replace the RTVS and support the NextGen initial capability. NEVS will provide an automated network-enabled web-based verification capability that is compatible with the 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.

Multifunction Phased Array Radar (MPAR)

The future conceptual approach to combined weather and airspace surveillance of MPAR will consolidate 510 radars of eight types, including weather radars and air surveillance radars, down to 334 radars of one type. MPAR addresses significant weather events (tornados, flooding, and aviation weather) that most directly affect people's lives, livelihoods, and the national economy. The goal of MPAR is to replace mechanically steered legacy radars with high-performance, electronically scanning radars through a disciplined risk-reduction program. For additional discussion of MPAR, see the discussion of Weather Radar Research in the Basic Services section.

NOAA Office of Oceanic and Atmospheric Research

Within NOAA's Office of Oceanic and Atmospheric Research (OAR), the Global Systems Division of the Earth Science Research Laboratory (ESRL/GSD) develops and evaluates aviation weather impact variables such as icing, turbulence, ceiling and visibility, convective weather, and volcanic ash as part of its development of algorithms and decision tools for NWS forecast offices, FAA traffic managers, and 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.

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 the following decision aids for aviation weather: Volcanic Ash Coordination Tool, FAA traffic management units coordination, and NWS CWSU coordination with the FAA. During FY 2010, GSD continued to support NWS aviation-support facilities in Ft. Worth, Texas; Anchorage, Alaska; and Leesburg, Virginia using FX-Collaborate applications.

For NextGen, the FAA is supporting GSD in developing capability to move relevant observation and forecast information into and out of the 4D Wx Data Cube (see detailed description above, in the FAA section of Aviation Services/Supporting Research Programs and Projects). Data

quantity, update frequency, timeliness, and latency are important performance considerations for this capability, which will become part of NNEW and the 4D Wx SAS (see descriptions above). GSD is working with the NWS, with funding from NOAA, to determine the best ways to populate the 4D Wx Data Cube with accurate, timely, and consistent observations and forecasts. Key areas of this effort include assessing the human role in the forecast process, evaluating the accuracy of these forecasts, development of operational forecasting concepts for the aviation impact variables, and putting all of these efforts together by creating a prototype dynamic 4D Wx Data Cube and its SAS subset.

The **National Severe Storms Laboratory (NSSL)** is participating in the effort to help quantify NOAA's support for the NextGen initiative. Planning with the FAA and the NWS began in FY 2009 and is anticipated to continue for the next several years. NSSL is also working with the FAA's AWRP to develop weather radar applications that enhance the safety and efficiency of the aviation community and the NAS. 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 3D grid of radar data that is being considered for inclusion in the 4D Wx Data Cube. 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. Work has also begun to bring in radar data from networks in other countries/regions to provide information in the 4D Wx Data Cube for regions outside the United States.

CLIMATE SERVICES

For purposes of this *Federal Plan*, Climate Services are those specialized meteorological services and facilities established to meet the requirements of Federal, state, and local agencies for information about trends in seasonal, interseasonal, or longer aspects of the atmosphere-hydrosphere-land surface system. Climate services include information on both oscillatory patterns (cycles varying over periods of several years to several decades) and longer-term secular trends in climate.

OPERATIONAL PROGRAMS INCLUDING PRODUCTS AND SERVICES

NOAA National Weather Service

Climate services are provided by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), through the National Centers for Environmental Prediction's (NCEP) Climate Prediction Center (CPC). CPC provides a broad range of products and services related to climate monitoring, short-term climate fluctuation forecasts, and information on the impacts of climate patterns on the Nation. Their product suite spans time scales from a week to seasons, extending into the future as far as technically feasible, and covers the land, the ocean, and the atmosphere. These services are available to government, public, and private industry users, both in this country and abroad. Applications include the mitigation of weather-related natural disasters and uses for social and economic good in agriculture, energy, transportation, water resources, and health.

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. The program fosters ties with other countries, other NOAA offices, other federal agencies, the university community, and the private sector. It encourages collaborative arrangements among Regional Climate Centers (managed by NOAA/National Environmental Satellite, Date and Information Service (NESDIS)), State Climatologists, and NWS WFOs and regional headquarters to tailor climate forecasts for local users. Additionally, WFOs issue daily and monthly climate reports for their areas, providing localized information about temperature and precipitation records and extreme events such as droughts. WFOs serve as the local NOAA user interface for climate services, including outreach and education in this area. They are also responsible for the integrity and continuity of the historical climate record in their area of responsibility.

Air Force Weather Agency, 14th Weather Squadron

The mission of the 14th Weather Squadron (14 WS) is to rapidly disseminate customized applied climatological and historical weather information to maximize combat effectiveness of DOD personnel and weapon systems, through expert receipt, quality control, storage, and tailoring of

earth-space environmental data. Climate information is used to analyze the past to help anticipate/predict the future. The 14 WS is DOD's authoritative source of historical weather data and environmental technical information, providing decision-enabling products and allowing command authorities to anticipate and simulate environmental impacts on all aspects of military operations worldwide. It enhances the combat capability of the United States by delivering timely, accurate, and reliable environmental situational awareness worldwide to the Air Force, the Army, Unified Combatant Commands, and the intelligence community. The squadron produces a suite of both standard and tailored products such as the Operational Climatic Data Summaries, Engineering Weather Data, Wind Roses, Wind Stratified Conditional Climatologies, among others, providing frequency of occurrence and duration for mission-limiting factors. The 14 WS employs the Point Analysis Intelligence System (PAIS) to produce historical, real-time, and forecast vertical profiles for any worldwide location in support of the intelligence community. The 14 WS also has a 6-month long range outlook capability that is computed using statistical methods, with an ensemble of global climate model forecasts, considering El Nino/Southern Oscillation, North Atlantic Oscillation, Southern Annular Mode, etc. The 14 WS' collocation with the National Climatic Data Center (NCDC) in Asheville, NC allows for data exchange as well as joint collaboration in areas such as data quality techniques, product development, and technology exploitation to facilitate and complement the mission of both organizations. The 14 WS also collaborates the Fleet Numerical Meteorological and Oceanographic Detachment-Asheville (FNMOD-A) and is a subordinate unit of the 2nd Weather Group (2 WXG), which is located at Offutt Air Force Base (AFB), Nebraska.

NOAA/NESDIS National Climatic Data Center

The National Climatic Data Center (NCDC) receives, processes, archives, and disseminates surface, marine, upper-air, radar, satellite, and model output data. NCDC serves a large and diverse community, responding to more than one million requests per year. It makes environmental data and information available through both the Internet and physical delivery of products and services. NCDC's climate data products support decision making in many sectors of the economy, including energy, transportation, agriculture, insurance, engineering, health care, and manufacturing.

NCDC also develops climatic applications for other government agencies, including the National Aeronautics and Space Administration (NASA), the Environmental Protection Agency (EPA), and the Departments of Defense (DOD) and Energy (DOE). In addition, NCDC scientists are key participants in numerous national and international climate assessments, including the Intergovernmental Panel on Climate Change reports, the U.S. Climate Change Science Program's Synthesis and Assessment Products, and the landmark 2009 Global Climate Change Impacts in the United States report. Through its participation in these assessments and dialog with users, NCDC actively identifies the needs of NOAA data users in addressing climate change.

Climate Data Records. In order to accurately detect subtle climate changes and variations, it is vital that the measurements from different satellites be merged together and analyzed using proven scientific techniques. The succession of prior satellites, with different designs and changing performance qualities, makes combining all past and current observations into consistent long-term records a major challenge. The Climate Data Records (CDR) Project, led by

NCDC addresses that challenge. The CDR Project will produce two important types of data records:

- CDRs are created from the initial data collected by satellites. Examples include atmospheric and sea surface temperatures, snow and ice conditions, and atmospheric greenhouse gas concentrations. CDRs reveal Earth's short and longer-term environmental changes and variations, allowing scientists to better understand the climate system; assess the state of the climate on regional, national, and global scales; and project future climate states.
- Climate Information Records are created from CDRs and provide specific information about environmental phenomena of particular importance to science and society. Examples include hurricane trends, Arctic sea ice coverage, and drought patterns. This information allows businesses, resource managers, decision makers, and the public to better understand and adapt to climate changes and variability, develop strategies to minimize risks, and mitigate possible impacts on society.

Environmental satellites remotely measure different Earth system properties from space. Over time, satellite sensors degrade and new satellites—sometimes with improved designs—are launched to continue the measurements. Without proper corrections, false trends in the data may be observed, caused by the observing system rather than the environment. These data can be accurately calibrated by measuring a well understood and slowly changing target, such as a barren desert, or by comparing these measurements with those made at the same time by other observing systems, including other satellites. These scientific corrections help create consistent and complete data records.

NOAA's CDR Project is: systematic because it progressively develops CDR using a consistent and well-defined set of improvement milestones; comprehensive because it encompasses a wide variety of both current and potential Climate Data Records and fully addresses management and preservation of these records; and sustainable because it supports continuous record updates and can incorporate improved techniques as they become available. In FY 2011, major CDR development and production actions include:

- Algorithm Development, Processing and Re-Processing of POES/GOES/NPP Data Series.
- Calibration, Validation and Characterization of Data.
- Science and Climate Information Records.
- Long-term Stewardship (ensure CDRs are easily understood, accessible and of highest quality possible).
- Applications for Climate Change Mitigation and Adaptation.

Climate Database Modernization Program (KY, MD, WV, and NC). The Climate Database Modernization Program (CDMP) is a partnership between NCDC and private industry to image and digitize key paper and microfilm records and to make them available via the Internet. There are more than 52 million images and over seven terabytes (1012) of data available online using Web Search Store Retrieve Display software. CDMP supports the NOAA mission to collect,

integrate, assimilate, and effectively manage Earth observations on a global scale ranging from atmospheric, weather, and climate observations to oceanic, coastal, and marine life observations. Many of these records, part of the U.S. National Archives, were originally recorded on paper, film, and other fragile media, and stored at various NOAA Centers. Prior to CDMP, these valuable data sources were not readily available to users and the paper and film media were deteriorating threatening their loss. Hourly weather records keyed through CDMP continue to be integrated into NCDC's long term historical climate records digital database holdings, extending the period of record for many stations into the latter 1800s. Daily paper data records collected mainly by the Smithsonian Institution and U.S. Army Signal Service from stations across the country keyed through the CDMP "Forts" project will extend climate records back to the early 1800s. Another major data integration task, the Surface Airways Observations project, will capture and key Weather Bureau and NWS data from major city offices and airports dating back to 1893.

The CDMP enables the digitizing of important environmental data ranging from below the oceans to the top of the ionosphere. Projects range from historic sunspot images, ocean core research, and extending time series data of ocean tides and sea level. CDMP is also coordinating several international projects, such as imaging and digitizing data from Uruguay and Mexico and upper air data from several countries in Africa.

In addition, collaboration with the British government will rescue observations from European ship logs. Increased easy and convenient storage, and access to increased volumes of digitized higher quality historical data improves NOAA's and others ability to monitor, assess, forecast, and predict environmental, solar, and geophysical events, and improve climate change projections. CDMP typically supports on average 77 ongoing Data Rescue Projects. Funding for projects are provided through a proposal process, which culminates each November at CDMP's Data Access Workshop. The imaging and digitizing is done under contract with the private sector.

Comprehensive Large Array-Data Stewardship System. The Comprehensive Large Array-Data Stewardship System (CLASS) stores the 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 technology. CLASS also supports convenient access to this data to users worldwide. In FY 2011, CLASS will address the anticipated increase in data volume of greater than 3,000 percent over the next several years and ensure environmental observations remain useful and accessible to the widest range of current and future users. It will ensure that environmental observations collected at great expense remain useful and understandable to the widest range of current and future generations. Users will be able to search for and acquire archived data by seamlessly connecting CLASS ingest, storage, and access capabilities with the NOAA Data Center archive management system. This increase also meets emerging requirements associated with implementing NOAA's climate services that include the long-term preservation of the Nation's climate record.

Global Observing System Information Center. The Global Observing System Information Center (GOSIC) provides access to data, metadata, and information from the Global Climate Observing System, the Global Ocean Observing System, and the Global Terrestrial Observing

System. 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 2010. 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 2010 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 climatology 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.

DEPARTMENT OF STATE (DOS)

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 socioeconomic 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 United Nations Framework Convention on Climate Change (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 United States. 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 time frame 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. DOS leads U.S. participation in the UNFCCC

negotiations, and is currently working towards an anticipated global agreement in Copenhagen in December 2009.

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 16 other major economies responsible for roughly 80 percent of the world's economic activity and 80 percent of the world's greenhouse gas emissions founded the *Major Economies Forum on Energy and Climate* (MEF). MEF Leaders' representative meetings were held in Washington, Paris, and Mexico, and at the Leaders' meeting at the L'Aquila G8 in Italy, a MEF Leader's declaration was issued. 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 of greenhouse gases and other 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 organizations and events 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 13 Federal agencies and is the umbrella to the 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.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

National Science Foundation (NSF)

In addition to ongoing efforts in basic climate research, modeling, and process studies, in FY 2011, the National Science Foundation (NSF) will be funding a major new effort in understanding the natural drivers that result in the oscillatory patterns of regional and global climate. The NSF-wide Investment: Science, Engineering and Education for Sustainability (SEES) includes a program that will fund work that seeks to: 1) achieve comprehensive, reliable global and regional predictions of decadal climate variability and change through advanced understanding of the coupled interactive physical, chemical, biological and human processes that drive the climate system; 2) quantify the impacts of climate variability and change on ecological, agricultural and other human systems, and identify and quantify feedback loops through which human systems help determine environmental outcomes; 3) maximize the utility of available observational and model data for impact and vulnerability/resilience assessments through up/downscaling activities; and 4) effectively translate model results and associated uncertainties into the scientific basis for well-informed human adaptation to and management decisions for climate change.

NOAA/NESDIS National Climatic Data Center

Climate Change Impacts Assessment. NCDC will continue to 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 as zoning and building codes), financial instruments (such as insurance and contingency funds), and emergency measures practices are all risk management measures that are 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 proactive adaptation to limit future impacts. NOAA's contributions to the recent Global Climate Change Impacts in the United States serve as a foundation for forthcoming assessment activities, See: http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts.

Renewable Energy. Renewable energy is energy generated from natural resources, including wind power and solar radiation, and energy from other naturally and constantly replenished sources (sunlight, rain, tides, geothermal heat, etc.). NCDC and National Renewable Energy Laboratory (NREL) have collaborated on applied research to develop a variety of products in support of renewable energy efforts. Such efforts focus on two areas:

- Solar Data: The National Solar Radiation Data Base (NSRDB) and NCDC's Integrated Surface Data (ISD) have been cataloged for advanced use in renewable energy research. In FY 2011, NOAA will continue to work to provide climate summaries useful in

estimating solar energy potential across the United States and in estimating heating/cooling requirements for buildings based on heat-gain from solar radiation.

- Wind Energy Data: There are several wind-related products available to the energy industry. The most comprehensive is a collection of gridded maps. The maps are based on hourly surface observational data, with the wind speed/direction data being used to then estimate the wind energy at various heights above ground. ISD were a key source of data for this effort. These data are extremely useful in estimating wind energy potential across the United States to determine locations where wind turbines and wind farms would be most practical, and NOAA will continue to develop these data sets in FY 2011.

Coastal Climatology Research. Information on coastal inundation risks are paramount as sea levels continue to rise. NCDC works to advance research leading to the development of products that have actionable operational use. The Pacific Region Integrated Climatology Information Products (PRICIP) project will improve understanding of patterns and trends of storm frequency and intensity ("storminess") within the Pacific Region. It will also develop a suite of integrated information products that can be used by emergency managers, mitigation planners, government agencies, and decision-makers in key sectors including water and natural resource management, agriculture and fisheries, transportation and communication, and recreation and tourism. PRICIP is exploring how the climate-related processes that govern extreme storm events are expressed within and between three, interacting theme areas: strong winds, heavy rains, and high seas. The PRICIP portal can be found at http://www.pricip.org/.

Global Tropical Cyclone Database Development. In FY 2009, NOAA unveiled the International Best Track Archive for Climate Stewardship (IBTrACS). IB-TrACS overcame data availability issues and freely disseminated this new and popular global data set. This was achieved by working directly with all the Regional Specialized Meteorological Centers and other international centers and individuals to create a global best track dataset, merging storm information from multiple centers into one product and archiving the data for public use. The IBTrACS project portal (http://www.ncdc.noaa.gov/oa/ibtracs/):

- Contains the most complete global set of historical tropical cyclones available.
- Combines information from numerous tropical cyclone datasets.
- Simplifies inter-agency comparisons by providing storm data from multiple sources in one place.
- Provides data in popular formats to facilitate analysis.
- Checks the quality of storm inventories, positions, pressures, and wind speeds, passing the information on to the user.

Paleoclimatology Reconstructions Network. NOAA Paleoclimatology has released the first product of its Paleoclimate Network (PCN), including 92 high-resolution temperature records over the past 2+ millennia in its archive. These records include global, hemispheric, regional, and local reconstructions, generally with annual time-step resolution. The records come with many categories of metadata. Each record is available as a separate ASCII file with fixed header and data formats, allowing machine reading of the data and time-step information. All the records

together are also available in netCDF, ASCII, and Excel formats, including the complete metadata within the files themselves.

Cryospheric Research. The National Snow and Ice Data Center (NSIDC, http://nsidc.org/), 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 CDMP. In addition, algorithms to detect snow, frozen ground, and sea ice in passive microwave images from DMSP and NASA satellites were 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.

NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory (AOML)

In an effort to better understand and forecast climate, OAR/AOML 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. 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 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.

Department of Energy (DOE), Office of Science

The Office of Science (SC) manages fundamental research programs in basic energy sciences, biological and environmental sciences, and computational science. In addition, the Office of

Science is the Federal Government's largest single funder of materials and chemical sciences, and it supports unique and vital parts of U.S. research in climate change, geophysics, genomics, life sciences, and science education. SC Climate Change Research is described in detail in the latest interagency report: *Our Changing Planet*, under the U.S. Global Change Research Program.

Climate and Evironmental Sciences Division

Within the SC Office of Biological and Environmental Research (OBER), the Climate and Environmental Sciences Division (CESD) focuses on a predictive, systems-level understanding of the fundamental science associated with climate change and DOE's environmental challenges—both key to supporting the DOE mission. CESD supports an integrated portfolio of research ranging from molecular to field scale studies, with emphasis on the use of advanced computer models and multidisciplinary experimentation. CESD supports three research activities and two national scientific user facilities.

Atmospheric System Research (ASR) Program. The ASR program seeks to resolve the two major areas of uncertainty in climate change projections: the role of clouds and the effects of aerosol emissions on the atmospheric radiation balance. In partnership with the Atmospheric Radiation Measurement Climate Research Facility (ACRF), the goal of the ASR is to quantify the interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics to improve fundamental process-level understanding, with the ultimate goal to reduce the uncertainty in global and regional climate simulations and projections. To accomplish this mission, ASR utilizes continuous long-term datasets that provide measurements of radiation, aerosols, clouds, precipitation, dynamics, and thermodynamics over a range of environmental conditions at several fixed and mobile ACRF sites situated in climatically diverse locations. These datasets are supplemented with laboratory studies and shorter-duration ground-based and airborne field campaigns to target specific atmospheric processes under a diversity of locations and atmospheric conditions. The long- and short-term data, together with model data, are employed to understand and parameterize the processes that govern the atmospheric components and their interactions over all pertinent scales.

Finally, ASR seeks to develop integrated, scale-bridging test beds for model parameterizations that incorporate this process-level understanding of the life cycles of aerosols, clouds, and precipitation in numerical models. To promote efficient implementation of improved atmospheric process understanding into DOE-supported coupled climate models, ASR participates in model activities with the division's modeling programs.

Climate and Earth System Modeling. Climate and Earth system modeling focuses on development, evaluation, and use of regional and global models, the development of Earth system models, and integrated assessment models to determine the impacts and possible mitigation, of climate change.

Environmental System Science. The Environmental System Science activity provides scientific understanding of the effects of climate change on terrestrial ecosystems, the role of terrestrial ecosystems in global carbon cycling, the basic understanding of terrestrial carbon sequestration,

and the role of subsurface biogeochemical processes on the fate and transport of DOE-relevant contaminants including heavy metals and radionuclides.

Two scientific user facilities—the ACRF and the Environmental Molecular Sciences Laboratory—provide the broad scientific community with technical capabilities, scientific expertise, and unique information to facilitate science in areas of importance to DOE.

Atmospheric Radiation Measurement Climate Research Facility (ACRF)

The ACRF is a multiplatform national scientific user facility, with instruments at fixed and varying locations around the globe for obtaining continuous field measurements of climate data. It promotes the advancement of atmospheric process understanding and climate models through precise observations of atmospheric phenomena. The ACRF was the first climate change field research facility to operate cutting-edge instrumentation on a long-term continuous basis. With its fixed research sites in three diverse climate regimes, representing mid-latitude, polar, and tropical environs (i.e., the southern Great Plains of the United States, the North Slope of Alaska, and the Tropical Western Pacific), and with an aerial (airborne) measurement capability and two mobile ground facilities, the ACRF provides the world's most comprehensive around-the-clock observational capabilities for obtaining atmospheric data specifically for climate change research.

Each ACRF site uses an array of cloud- and aerosol-observing instruments to record long-term continuous atmospheric and surface properties that affect cloud formation and radiation transport through the atmosphere. The ARCF also provides shorter-term (months rather than years) measurements with its two mobile facilities and aerial measurement capability. This approach of combining long-term, fixed-site measurements with short-term mobile measurements allows unique examination of the behavior of fundamental atmospheric processes—and the evaluation of climate model performance with respect to those processes—over a wide range of climatic and meteorological conditions. Data from the sites are available through the data archive established at Oak Ridge National Laboratory. These data are used as a resource for over 100 journal articles per year.

National Aeronautics and Space Administration (NASA)

Earth Science Division

Climate services, whether global or national, will require development and delivery of data, tools, and information that are science-based, user-responsive, understandable, credible, and relevant to decision makers. Climate services will be an integrated system that links essential observations, data, research and analysis, and predictions to the iterative development of service-oriented information for societal benefits. According to the U.S. Government Report to the World Meteorological Organization High-level Taskforce for the Global Framework for Climate Services, core climate service elements should include: new scientific knowledge to improve climate services; balanced, credible, cutting-edge scientific and technical information; long-term changes in trends in climate and changes in natural variability; multi-disciplinary approaches that address economic, social, and cultural issues; development of science-based products and services to minimize climate-related risks; regional and local projections of climate change;

observing systems and linkages between systems, standards, and data stewardship; data distribution with minimum time delay and minimum cost; timely assessments; and climate literacy and workforce development.

The 2010 National Space Policy stated that NASA plays a crucial role in global climate change research and sustained monitoring capabilities, and advances research into and scientific knowledge of the global integrated Earth system by accelerating development of new Earth observing satellites. The NASA program on global climate change research is comprehensive, encompassing continuous interactions between satellite mission development and formulation, satellite data analyses, Earth system modeling, new technology, and state-of-the-art scientific knowledge for applications. Scientific research and data analysis are conducted through the open, transparent proposal peer-review Research Opportunities in Space and Earth Sciences (ROSES).

More than 30 years ago, NASA pioneered the interdisciplinary field of Earth system science, which is the study of Earth as a global integrated system. Global climate change is an essential component of Earth system science. NASA climate activities encompass 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. NASA's goal is to understand the changing global climate, its interaction with life, and how human activities affect the environment. In association with national and international agencies, NASA applies this understanding for the benefit of society.

NASA's climate program is unique throughout the world because it is an end-to-end one that encompasses the development of observational techniques and the instrument technologies needed to implement them; laboratory testing and demonstrations from an appropriate set of surface-, balloon-, aircraft-, and space-based platforms; development and operation of satellite missions and production and dissemination of resulting data products; research to increase basic process knowledge; incorporation of results into complex computational models that can be used to more fully characterize the present state of the environment and predict the future evolution of the Earth system; and development of partnerships with other national and international organizations that can use the generated information in environmental forecasting and in policy, business, and management decisions.

Satellite Missions. Satellites provide critical climate change measurements via global coverage, frequent sampling in both space and time, and near-uniform accuracy and stability. NASA initiated, and in selected cases sustained for more than a decade, many global, high accuracy, well-calibrated data records; such as, total solar irradiance at the top of the atmosphere; Arctic Ocean sea ice extent and thickness; Antarctic and Greenland ice-sheet thicknesses, global sea level, global ocean surface vector wind; global ocean near-surface chlorophyll-*a* concentration; global land use and land cover; ozone in the stratosphere; and global precipitation, including water vapor, rainfall, and snow. These critical climate data records are a foundation for national and international studies of global and regional climate change.

At the beginning of FY 2010, NASA operated 15 on-orbit satellites that produce climate relevant data. On October 11, 2009, and November 23, 2009, respectively, the ICESat and QuikSCAT satellites ceased their primary geophysical missions after many years of extended service.

The daunting challenge of the complexity of global and regional climate change science is the huge number of biological, chemical, and physical variables that must be measured simultaneously at all locations. To approximate a solution, NASA engineered constellations of satellites flying in close formation. NASA's Aura, CALIPSO, CloudSat, and Aqua satellites, together with the French PARASOL satellite, are called the "A-Train" constellation and produce an unprecedented quantity of data for atmospheric chemistry and composition. The time separation between the front and rear of the A-Train is 7 minutes, less than the lifetime of most clouds; this important feature allows researchers to utilize multi-satellite observations to examine specific processes related to cirrus cloud formation in large-scale models. In December 2009, PARASOL's limited fuel supply caused it to be placed at an orbit lower than the 705-km orbit of the A-Train.

Every two years, NASA evaluates the extension of missions that have completed their primary mission or will complete the primary mission in the two years following the evaluation review. In April-May 2009, 13 missions were reviewed for continued relevance of their science objectives and the routine use of their near-real-time data products to advance the objectives of operational agencies, which ranked the operational utility of each mission as "very high," "high," "some," or "none." A "very high" utility meant that the data were routinely used and loss of data would have significant negative impact on operational objectives. A "high" utility meant data were routinely used data and loss of data would measurably impact the operational agency's mission. Data from all NASA satellites were utilized by other agencies. Satellites with "very high" utility were Aqua, Aura, CALIPSO, GRACE, ICESat, Jason-1, QuikSCAT, SORCE, Terra and TRMM. The satellite with "high" utility is CloudSat. The next Senior Review for mission extension will occur in 2011.

Artist's rendition of Glory in orbit. Credit:NASA

NASA has 7 missions in development for launch from 2010 to 2015. Five missions (Glory, Aquarius, NPP, LDCM, and GPM Core) are foundational missions, which the Decadal Survey assumed would be precursors to Decadal Survey missions. Two missions, SMAP and ICESat-II, are Tier I Decadal Survey missions.

The President's FY 2011 Budget Request funds a Climate Change Initiative that will greatly accelerate NASA's formulation, development, and launch of all 15 Decadal Survey missions assigned to NASA; all Decadal Survey are relevant to research on global and regional climate change. Launch readiness dates of the remaining Tier 1 Decadal Survey missions, CLARREO and DESDynI, were moved up to 2017. The Initiative will make possible a larger number of Decadal Survey missions in the coming decade. For example, the budget enhancement advances

the average launch readiness date of each Tier 1 mission, two Tier 2 missions (ASCENDS and SWOT), and a Venture-class satellite mission by about 30 months.

The President's FY 2011 Budget Request also recognizes the need for continuity in critical climate observations and data records and continues funding to develop an Orbiting Carbon Observatory (OCO-2) mission to measure atmospheric carbon dioxide to replace the mission that failed to reach orbit in 2009, with a target launch readiness date of early 2013. NASA will also begin development of a GRACE-Continuity mission working towards a launch readiness date in 2016; refurbish a SAGE-III instrument to measure aerosols, ozone water vapor, and other trace gases in the upper troposphere and stratosphere as early as 2014; and a Pre-ACE (called PACE) mission to measure ocean color, clouds, and aerosols as early as 2018.

The Decadal Survey recommended creation of a Venture-class program of small, frequent, predictably scheduled science mission opportunities to spur innovation and enable the training of future Earth science leaders. In 2009, NASA released the Earth Venture-1 (EV-1) call for extended airborne science observing campaigns. Selections of five EV-1 airborne investigations were announced in May 2010, with field campaigns to run from 2011 through 2015. The selected EV-1 missions will investigate: soil moisture in major ecosystems as it relates to the uptake or emission of carbonaceous gases (e.g., carbon dioxide and methane); the exchange of water vapor and other chemical constituents between the stratosphere and troposphere along with cirrus cloud properties and chemical processes with a variety of instruments on NASA's Global Hawk unattended airborne system (UAS) in widely separated areas in the tropical Pacific; the emission of carbon dioxide, methane, and other gases from Arctic permafrost with a variety of instruments deployed on aircraft and on the ground; the air quality impact of aerosols, ozone, and other gases over a number of major North American urban areas utilizing NASA's B-200 and P-3B aircraft to improve the use of satellite remote sensing in air quality assessment and forecasting; and tropical storm development with instruments deployed on two NASA Global Hawk UASs which can remain aloft for up to 30 hours. NASA plans to release the first call for a complete space flight mission, EV-2, in 2011, with selections to be made in 2012. The solicitations for sub-orbital and orbital missions will continue in alternate years. The President's FY 2011 Budget Request also provides funding for an annual solicitation to develop satellite instruments for a mission of opportunity; the first solicitation, called EV-3, will occur in 2011.

Technology Development. Technology investments are aligned primarily with Decadal Survey activities, but may also support the foundational and climate continuity missions. Such investments focus on maturation of technologies to enable advanced space-based observations and modeling to improve understanding of the global integrated Earth system including global and regional climate change. The Earth Science Technology Program provides funding for instrument, component, and information technologies prior to mission formulation. Developing and validating technologies well in advance of a flight project help to improve acceptance and reduce costs. Projects are initiated each year through the ROSES open, peer-review, competitive proposal process; duration of each project is typically three years. In 2007, 57 projects were started. In 2009, approximately 53 percent of projects achieved quantifiable improvements in technology readiness. Four examples are described. The Far Infrared Spectroscopy of the Troposphere project successfully obtained measurements in the far-infrared region of the Earth's infrared emission spectrum critical to understanding radiative feedbacks associated with global warming. The Pathfinder Advanced Radar Sounder instrument successfully measured basal

topography and internal layering of ice sheets in Greenland that will enhance our understanding of ice-sheet mass changes. Field tests of the Tropospheric Infrared Mapping Spectrometer instrument demonstrated a low-risk, no-moving-parts design for improved column carbon monoxide measurements. A proof-of-concept Glacier and Land Ice Surface Topography Interferometer K_a-band radar instrument generated both imagery and high-precision topographic maps of glaciers and ice sheets. New project solicitations will be released in 2011 through ROSES.

Airborne Platforms. NASA supports a wide range of piloted and unattended airborne systems to enable more effective utilization of satellite missions, including calibration and validation of satellite measurements, including algorithms; observations that fill satellite measurement gaps, e.g., airborne measurement of vertical distribution of an atmospheric variable which a satellite measures as a column average; fundamental research on processes within the global integrated Earth system that satellite measurements have yet to observe; continuity of satellite measurements in selected geographical regions to mitigate a data gap that occurs between the end of a satellite mission and the start of the next mission; and, test of new sensor technologies in space-like environments. Three NASA airborne assets, the ER-2 (operates with a pilot at 22-km altitude), WB-57 (operates with 2 pilots at 20-km altitude), and Global Hawk (operates unattended at 20-km altitude with an 11,000 nautical-mile range and 31-hour duration), are world-unique flying laboratories for global integrated Earth system science.

In FY 2009, the UAVSAR instrument on the Gulfstream-III became operational with data acquisition for terrestrial ecology and hydrology sciences during the International Polar Year. The multi-year IceBridge campaign was inaugurated with more than 400 hours of P-3B and DC-8 flight time for measurements of sea ice thickness and extent and glacier elevation. Also in FY2009, a superpod nacelle was mated to the WB-57 wings, and the aircraft was certified for a higher gross weight. The SIERRA UAS flew its inaugural science mission when it characterized Arctic sea ice. The Global Hawk UAS flew its first NASA flights using a totally redesigned ground operations center.

In FY 2009, NASA established the Student Airborne Research Program (SARP) for students to acquire hands-on research experience in all aspects of a scientific campaign onboard the DC-8, which is a major NASA resource for study of global integrated Earth system processes and calibration/validation of space-borne observations. Students operated the Whole Air Sampler and the MODIS/ASTER Airborne Simulator instruments onboard the DC-8 to sample atmospheric chemicals and to image land and water surfaces in multiple spectral bands. Twenty-two undergraduate and graduate students were selected through an open application process. Three students presented their results at the American Geophysical Union Meeting in San Francisco during December 2009. SARP continued for a second year in summer 2010 when 27 students conducted airborne research using the same airborne facilities as in the previous year but with different scientific aims over different areas of California.

Computing Capacity and Capability. Global climate change modeling requires extensive state-of-the-art computing capability and capacity. In June 2010, NASA established the NASA Center for Climate Simulation (NCCS) at the NASA Goddard Space Flight Center, Greenbelt, MD. The NCCS provides an integrated set of supercomputing, visualization, and data interaction technologies that doubled the processing speed with peak performance of 159 trillion operations

per second; substantially reduced the horizontal resolution of climate models to 3.5 kilometers, equaling the highest resolution for a global climate model and adequate to capture a snowstorm and the eye of a hurricane; offered a larger memory of 35 terabytes distributed over 15,000 processing cores, and the number is expected to double in FY 2011; increased disk storage to 3 petabytes; and included an Earth System Grid for distributing simulation data from NASA's contribution to the forthcoming Fifth Assessment Report of the Intergovernmental Panel on Climate Change. The NCCS climate model produces 8 terabytes of model output per day. To enable study of climate model results, the NCCS designed and installed its Data Exploration Theatre, a 17-by-6 foot visualization wall combining fifteen 46-inch high-definition screens into a display system totaling 14 million pixels.

Data Information and Systems. NASA promotes the full and open sharing of all data with the research and applications communities, private industry, academia, and the general public. This includes observations, metadata, high-level data products, images, science results and many other types of information. NASA promotes the sharing of models and other analysis tools along with related documentation and source code. NASA adheres to the principle of non-discriminatory data access so that all users are treated equally; there is no period of exclusive access to NASA data.

NASA records more than 4 terabytes of data every day and maintains the world's largest scientific data and information system to process, archive, and distribute data and information products created from satellite data. NASA's 12 specialized data centers process, archive, document, and distribute data products, and provide services and data-handling tools for NASA's past and current satellite missions and field measurement programs.

NASA is using advances in information technology to expand its capabilities to support societal benefits, many of which require rapid utilization of satellite data. Operational agencies and others sometimes require data having a latency less than 3 hours (compared to about 40 hours for science-quality data) for a wide range of activities, including mitigating effects to natural hazards and forecasting air quality, invasive species, and weather. Compared to standard science-quality data, near-real-time data have less accurate ancillary data, such as geolocation. The Land Atmosphere Near-real-time Capability for EOS (LANCE) provides access to data within 3 hours from the time of observation for data recorded from the AIRS, AMSR-E, MLS, MODIS and OMI instruments on the Aqua and Aura satellites. Science instrument teams validate near-real-time data. Near-real-time data are available from a 7-day rolling archive and are provided on a best-effort basis. LANCE is supported during normal working hours and is monitored for system failures and unexpected data outages. The one-stop-shop LANCE website was inaugurated in March 2010, and MODIS land surface temperature was added in May 2010. A MODIS rapid response system was integrated into LANCE in August 2010 and a LANCE User Working Group was established in September 2010. Plans for LANCE in FY 2011 include the integration of a fire information management system and a flood mapping capability.

The Americas ALOS Data Node (AADN) is located at the Alaska Satellite Facility, a NASA Distributed Active Archive Center, and, in association with the Japan Aerospace Exploration Agency (JAXA), distributes JAXA ALOS data recorded from the AVNIR-2, PRISM, and PALSAR instruments to users in Central, North, and South America; special conditions apply for

Brazil and Canada. In April 2010, the acquisition of ALOS data through the NASA TDRSS was declared operational in a ceremony in Japan.

Fundamental Research

The current suite of 13 operating satellites missions, as well as numerous previous missions, provides unprecedented data for new discoveries about how the Earth system works and how it changes on various time scales. NASA's Earth Science Division supports researchers through the ROSES open, peer-review, competitive, proposal process. In FY 2009 and FY 2010, 906 and 861 projects were funded, respectively. Representative research results achieved in 2009 and 2010 and relevant to OFCM guidelines are described below in four major scientific themes of the global integrated Earth system: Atmospheric Composition, Climate Variability and Change, Global Water Cycle, and Global Carbon Cycle.

Atmospheric Composition. Atmospheric composition changes affect air quality, weather, climate, and critical constituents such as ozone. Atmospheric exchange links terrestrial and oceanic reservoirs within the carbon cycle and water cycle. Solar radiation affects atmospheric chemistry and is thus a critical factor in atmospheric composition. Atmospheric composition is central to Earth system dynamics because the atmosphere integrates surface emissions globally on time scales from weeks to years. NASA research on atmospheric composition furthers our understanding and capability for prediction of the recovery of stratospheric ozone and its impacts on surface ultraviolet radiation, of the evolution of greenhouse gases and their impacts on climate, of the evolution of tropospheric ozone and aerosols and their impacts on climate and air quality, and of other issues.

NASA atmospheric composition research addresses the following questions: how is atmospheric composition changing; what trends in atmospheric composition and solar radiation are driving global climate change; how does atmospheric composition respond to and affect global environmental change; what are the effects of global atmospheric composition and climate changes on regional air quality; and how will future changes in atmospheric composition affect ozone, climate, and global air quality?

A new research investment is the unattended airborne system Global Hawk, which can stay aloft at an altitude of 65,000 feet for 30 hours with a 12,000-mile range. Global Hawk completed its inaugural science mission (called Global Hawk Pacific or GloPac) in April 2010. On the second flight of five, the Global Hawk, fitted with 11 instruments, flew from California to Hawaii to near the equator and then to 85°N over the Arctic Ocean, spending 8 hours over sea ice, before landing in California. GloPac measured greenhouse gases, ozone-depleting substances, aerosols, and constituents of air quality in the upper troposphere and lower stratosphere. During the long southbound journey over the Pacific, the Global Hawk flew under the tracks of the Aura and CALIPSO satellites for calibration of satellite data.

NASA's innovative techniques in analyses of satellite measurements continually finds new measurement capabilities hidden in data that were primarily recorded for other purposes. Atmospheric carbon dioxide is such an example. In addition to achieving success its primary objective, enhancing weather forecasting, the AIRS instrument on Aqua has produced mid-level atmospheric carbon dioxide data. The TES instrument on Aura was not originally designed to

measure atmospheric carbon dioxide, but a validated TES carbon dioxide data product now exists. NASA's OCO-2 mission, scheduled for launch in 2013, will provide CO_2 measurements with significant sensitivity to the lower troposphere over land and ocean.

Aerosols can harm human health and are a large source of uncertainty in predicting the future behavior of climate because some aerosols, such as soot (known as black carbon), absorb incoming solar radiation to heat the atmosphere while other aerosols; e.g., dust, reflect incoming solar radiation to cool the atmosphere. Analysis of airborne aerosol measurements collected throughout the Pacific Ocean basin revealed that increased aerosols from combustion are directly and indirectly influencing climate. Aerosols over the pristine Amazon rainforest approximate pre-industrial conditions, and aerosol-cloud interactions in this environment are distinctly different from those in polluted regions.

Satellite measurements of aerosols, including aerosol injection generated by fires, are sufficiently long for global climatologies to be established, which is a necessary precursor for studies of spatial and temporal characteristics of global climate change. Maximum injection height of fire-generated aerosols in boreal and temperate regions of North America occurred in June-July. High aerosol loading from anthropogenic black carbon over the Indian subcontinent in March-May would elevate the natural heat pump for the southwest monsoon.

Global observations of aerosols and other variables from A-Train satellite sensors allow climate-related studies on aerosols that are not possible from single sensors alone. In a first study of its kind, NASA satellite data (OMI on Aura; MISR on Terra; CERES on Aqua and Terra; and MODIS on Aqua and Terra) and in-situ measurements (AERONET) revealed, that within the net radiative effect of dust, the long-wave effect dominates over a desert and the short-wave effect dominates over the ocean. Not all aerosols absorb solar radiation equally because of aerosol composition variations, an important variable for climate modeling. AERONET optical measurements revealed that the aerosol absorption optical depth was near unity (theoretical limit for black carbon) for industrial aerosols, about 10 percent larger for aerosols from biomass burning, and twice as large for desert dust. The NASA Glory mission, scheduled for launch in 2011, will use this feature to detect aerosol composition.

Carbon monoxide (CO), a weak greenhouse gas, is an ozone precursor gas and a pollutant. CO is a product of incomplete combustion, and its main global sources are biomass burning, fossil fuel combustion (including passenger vehicles), agricultural waste burning, biofuel combustion, and industrial production. NASA satellite data (AIRS on Aqua; TES on Aura; and MOPITT on Terra), non-U.S. satellite data (SCIAMACHY on Envisat), and a NASA chemical transport model (GEOS-Chem) showed that CO sources had been underestimated in winter at northern mid-latitudes. CO emissions in winter were 50 percent higher than in summer in the U.S. and Europe and 100 percent higher in eastern Asia, presumably from residential heating and vehicle cold starts. These results indicate an underestimation of biomass burning measurements in the Global Fire Emission Database. For a regional CO emissions, such as industrial production in the northeast U.S. and biomass burning in Brazil, the characteristic zonal and meridional scales of the surface temperature response caused by radiative forcing would be 12,000 and 35,000 km, respectively, extending the climate impacts of CO and other radiatively active pollutants thousands of km beyond the source. The world's megacities' emission of methane, a more potent

greenhouse gas than CO, could contribute 7-15 percent of the total global anthropogenic quantity of methane, which is substantially higher than currently estimated.

One factor missing from climate models of Arctic warming is proper representation of the size, composition, and distribution of aerosols in the Arctic, which is a major receptor for mid-latitude pollution. Springtime airborne measurements in the Arctic revealed a large amount of mid-troposphere aerosols (so-called Arctic haze), which had been produced in middle latitudes. Aerosols from fires and urban pollution penetrated the Arctic from all three Arctic continents, and mid-latitude Asian pollution was the strongest source of Arctic aerosols except near the surface, where European anthropogenic emissions were dominant. AIRS carbon monoxide data demonstrated a correlation between the El Nino and Asian pollution transport to the Arctic, apparently through teleconnections between tropical Pacific sea surface temperature and the strength of the Aleutian Low. Over the past 30 years, the Arctic surface air temperature has risen faster than any other large-scale region on Earth and apparently aerosols, especially Asian black carbon emissions, contributed nearly 75 percent of the 1.5 °C increase. Northern Hemisphere pollutants from power generation, industry, and on-road transportation contribute substantially to the warming in the Arctic.

The eruption of Iceland's Eyjafjallajokull Volcano in April-May 2010 enabled an outstanding display of NASA science and technology for immediate societal benefit. While many satellites measured the presence of ash plumes during daylight, CALIPSO's lidar instrument revealed the altitude of ash clouds, which greatly assisted advisory centers issuing warnings to pilots. The MODIS instrument on Aqua captured a nighttime image of the ash plume because of differences in heat radiated by the ash and the surrounding ocean and clouds. OMI and MISR instruments on Aura and Terra, respectively, and the ground-based AERONET also monitored the volcanic ash plume which, had it penetrated the stratosphere and contained a much larger mass, may have had a short-term climate impact. The MISR Plume Height Climatology Project was expanded to include volcanic plumes beginning with Eyjafjallajokull data.

While the Eyjafjallajokull Volcano did not emit a great quantity of sulfur dioxide (SO_2), other volcanoes do. Volcanic SO_2 produces sulfate aerosols in the atmosphere. These sulfates, if injected into the upper troposphere and stratosphere, would remain in the atmosphere for months to years, affecting the global radiation budget and cloud microphysics. A new technique has been developed for direct retrieval of the vertical abundance of SO_2 with NASA satellite measurements.

The global extent of wildfires has a profound impact on global climate and air quality through emissions of CO, CO_2, nitrogen oxides, methane, and aerosols. A first-ever global fire model validated on a global scale with satellite data, the only source of consistent information on fires on a global scale, has been developed. Hydrogen cyanide, a fire-produced pollutant, found in the lower stratosphere over India and Tibet had apparently originated from Indonesian fires and was then transported by the southwest monsoon circulation over the Indian Ocean and then convectively uplifted into the stratosphere with potential for global distribution. Pyrocumulonimbus, a fire-started or augmented thunderstorm that injects large amounts of smoke and other biomass burning emissions into the lower stratosphere, was discovered through innovative analyses of NASA MLS, SAGE-II and TOMS data.

Tropospheric ozone, an air pollutant produced by the chemical reaction of sunlight with nitrogen oxides and volatile organic compounds in the atmosphere, lowered the value of the soybean crop in Illinois, Indiana, and Iowa by 10 percent (or $1 billion) by reducing membrane permeability, which leads to early desiccation and necrosis. With a 1 parts-per-billion increase in tropospheric ozone, soybean yields decreased by 1.5 bushels per acre. In the temperate forests of the eastern U.S., tropospheric ozone reduced net primary production about 8 percent over the past century, when nitrogen deposition had a greater influence on increasing net primary production than elevated carbon dioxide.

Evidence of the success of the Montreal Protocol is shown from ground-based measurements of stratospheric chlorofluorocarbon 12 (CCL2F2) at Kitt Peak National Observatory near Tucson, where CCL2F2 was increasing at the rate of 1.5 percent per year at the beginning of the data record in 1977 compared to 2009 when the trend decreased at 1.5 percent per year.

Climate Variability and Change. Variations of oceans, ice-sheets, and sea ice and their mutual interactions represent major impacts of global atmospheric warming and a substantial portion of global climate change models, although climate models are now incorporating ocean and terrestrial biospheres. Sustained observations are required to isolate long-term trends from large-amplitude, shorter-period fluctuations. To develop improved models of future climate evolution, greater knowledge is needed of ice-sheet mass balance and dynamics, including ice-sheet flow and ice shelves; sea ice extent and thickness; and global ocean general circulation, including heat transport and air-sea interactions.

NASA's IceBridge mission collects data in the Arctic and Antarctic to extend the record of ice observations begun by ICESat, which ceased operation in October of 2009. Notable activities in 2010 included an Antarctic flight that crossed every ICESat orbit and thousands of kilometers of flights over ICESat tracks in the Arctic and Antarctica. During these flights, critical data were also collected by radar and gravity methods to map the ice bed as well as the sea floor underlying floating ice shelves. In Antarctica, these maps revealed structures that allow warm Antarctic deep water to penetrate the far reaches of these ice shelves and destabilize them. NASA also established a data archive for IceBridge data at the National Snow and Ice Data Center.

NASA's precision satellite altimetry measurements of global sea level began in 1992 and have revealed a rise in sea level of about 3.3 mm/yr from January 1993 to September 2009. The rise is primarily caused by ocean thermal expansion and inflow of melt water from land, such as from Greenland where warm ocean waters melt a considerable amount of the calving fronts of glaciers and where surface melt accounts for roughly half the mass loss from the ice sheet. The rapidity of ice-sheet movement in Greenland and Antarctica has affirmed the need for more realistic ice-sheet models that incorporate bed topography and basal conditions; NASA is supporting this enterprise to generate a more accurate estimate of ice-sheet contribution to sea level rise. Because in-situ measurements of ocean warming do not have the consistency of satellite data, efforts continue to narrow uncertainties of upper-ocean warming estimates to improve assessments of the sea level budget, global radiation imbalance, and climate models. Satellite altimetry measurements in the North Atlantic Ocean showed a 15 percent increase in the mean northward-flowing upper portion of the Atlantic Meridional Overturning Circulation from 1993 to 2009.

Meandering frontal zones, which occur throughout the ocean, have traditionally been observed with sea surface temperature, which restricted detection to regions of adequate sea surface gradient to define the frontal region. Patterns of skewness and kurtosis of precision satellite sea surface topography measurements offer an alternate approach to finding frontal zones, including newly discovered fronts in the Southern Ocean.

The El Nino phenomenon, which reoccurs at irregular intervals of 3 to 7 years in the uppermost 300-500 m in the tropical Pacific Ocean where an operational ocean observing system exists, is an excellent test bed to refine ocean data assimilation techniques for analyses of seasonal-to-interannual coupled ocean-atmosphere interactions. Observations indicate that the intensity of El Nino events in the central Pacific has almost doubled over the past 30 years, causing a long-term warming trend of sea surface temperature in the central Pacific. This could influence model-generated forecasts of the onset of El Nino. NASA's GMAO global coupled ocean-atmosphere-land general circulation model produced improved simulations of the 2006 El Nino event through assimilation of the vertical distribution of salinity. In the El Nino region, estimating air-sea freshwater fluxes; i.e., evaporation minus precipitation, from sea surface salinity measurements recorded by the Aquarius mission will be challenging because of ocean dynamics. Aquarius is expected to launch in mid-2011.

Global Water Cycle. One of the most significant effects of global warming is an alteration of the global water cycle. NASA's global water cycle studies are enabling improved predictions of water cycle consequences of global integrated Earth system variability and change. This challenge requires knowledge of the Earth's water cycle related to global climate variability and change, which alter the frequency, geographical distribution, and intensity of natural meteorological and hydrological events. Interpretations of water cycle trends, extreme events, and abrupt changes, which are estimated through assimilation of satellite and in-situ observations into global prediction models, are emphasized. The global water cycle has obvious and significant implications for the health and prosperity of society.

Consistently processed satellite data now have durations sufficiently long for water cycle trend analyses. A 10-year climatology of TRMM vertical radiative heating profiles showed the strong influence of clouds, water vapor, and large-scale dynamics on regional radiation budgets. The mean annual maximum areal extent of surface water (non-ice) reservoirs, such as rivers, lakes, wetlands, and irrigated regions, decreased approximately 6 percent from 1993 to 2004, with the largest impact in the tropics from 1993 to 2000. Variations in surface height of lakes and reservoirs as small as 150 km^2 with a width as small as 800 m can be measured with a root-mean-square accuracy of 3-33 cm, depending on the size of the lake or reservoir. The Decadal Survey Surface Water and Ocean Topography (SWOT) mission is expected to dramatically reduce this uncertainty.

Developing climatology of gale-force ocean winds is challenging because of the scarcity of observations: ships generally avoid high winds. A 10-year QuikSCAT climatology of Gulf of Tehuantepec high-wind-speed events revealed nearly 12 gale-force (wind speed >34 knots) events and 6 storm-force (> 48 knots) events during November-March, with most gales and storms occurring in December and January, respectively.

The amount of water vapor in the stratosphere influences the temperature of the troposphere through radiative effects: increases (decreases) in stratospheric water vapor warm (cool) the troposphere. Stratospheric water vapor measurements from a sequence of NASA instruments (HALOE, SAGE-II, and MLS) showed a decrease of about 10 percent after 2000, which modeling studies indicated would slow the rate of increase in global warming from 2000-2009 by 25 percent.

Precipitation, whether as solid or liquid, is not well observed throughout the world and estimating global precipitation is a challenge. NASA's multi-satellite microwave precipitation data product, which is independent of the occurrence of clouds, combines measurements from the TMI, SSMI, AMSR, and AMSU instruments. Many evaluation tests showed the reliability of the data product, including 1-day rainfall totals during the extreme flooding around Atlanta, GA, in September 2009. For geostationary satellite data, a multi-spectral technique (6.5 and 10.7 mm) was 20 percent and 50 percent more accurate in rain rate and rain/no-rain detection, respectively, than a single thermal infrared spectral channel (~11 μm). An improved rainfall algorithm estimates cloud development and dispersal streamlines through successive geostationary images and then locally collocates rainfall to the clouds with polar-orbiting microwave rainfall measurements. Merging satellite rainfall measurements with in-situ rain gauge data reduced satellite rainfall measurement bias. Integrating cloud and multispectral information improves rain estimation in summer over the United States.

A causative factor in generating precipitation is upward motion in the lower atmosphere associated with surface wind convergence, which has a strong diurnal periodicity and which over the global ocean is a challenge to observe because of the absence of surface wind vector measurements. In a one-time occurrence lasting six months in 2003, two identical SeaWinds instruments on two different satellites (QuikSCAT and ADEOS-II) revealed a rich diurnal variability pattern, which influenced cloudiness, cloud liquid-water content, and precipitation, over a large fraction of the global ocean within 20-30° of the equator.

The accurate portrayal of the presence or absence of clouds in weather and climate models has long been recognized as a source of large uncertainty in weather forecasts and climate predictions. Progress is being made on classification of clouds in geostationary satellite data. The vertical profile of clouds influences the estimation of the radiative flux divergence within and at the top of the atmosphere. Cloud-base height influences the surface radiation budget, particularly in polar regions. A new method using geostationary satellite measurements has been developed to derive ice water content for the top portion of deep convective clouds and anvils. Observations of multi-layer clouds and cloud thicknesses were especially challenging until the CALIPSO and CloudSat missions were launched in 2006; these satellites measure nearly the same volumes of the atmosphere within 15 seconds of each other. The annual cycle of global cloud cover derived from these satellites' data had a minimum of 74 percent in March and maximum of 78 percent in October. An improved CALIPSO cloud phase determination algorithm has been developed using the spatial correlation of layer-integrated attenuated backscatter and layer-integrated particulate depolarization ratio.

An obstacle to developing accurate cloud parameterizations for the stratosphere is incomplete knowledge about the presence of clouds. NASA satellite measurements (CALIPSO, MLS on

Aura) showed that convection is an important water source for clouds in the lower stratosphere in mid-latitudes in the Northern Hemisphere, especially over North America.

The latent heat released during phase changes of water is the dominant component in the atmospheric energy budget in the tropics. The atmospheric response to heating is sensitive to its vertical distribution. TRMM data have sufficient fidelity to show that latent heating profiles over the west Pacific warm pool simulated with a 2-dimensional cloud-resolving model were more representative than those computed with a 3-dimensional cloud-resolving model. TRMM precipitation radar data were instrumental in developing an improved method to estimate very high vertical resolution latent heating profiles. TRMM-derived vertical latent heating profiles determined rain-rate intensity within the Madden-Julian Oscillation (MJO), which is a fundamental mode of the tropical atmospheric circulation and is poorly represented in global models. For the MJO water cycle, precipitation and moisture convergences were nearly balanced throughout the atmosphere column, with surface evaporation being much smaller.

Knowledge of extreme deep convection with cloud-top heights exceeding 10 km has been revolutionized with TRMM Precipitation Radar data. This phenomenon occurs infrequently throughout the globe but is relatively common in the evening in the pre-monsoon (March-May) and monsoon (June-September) periods in India's east coast and western Himalayan foothills, respectively.

Global warming produces a wetter atmosphere, and how much wetter is a subject of debate. Theoretical considerations indicate the amount of water in the atmosphere should increase 7 percent for a 1 °C rise in surface temperature. AIRS data in summer over northern Eurasia showed that the total precipitable water increased 3 percent per 1 °C, indicating that climate models may be overestimating the strength of the moisture-driven greenhouse warming at middle latitudes during summer.

Quantifying the components of the terrestrial water cycle is key to understanding availability of water resources and to predicting extremes such as droughts and floods. For large scales and especially in less-developed regions the paucity of in-situ observations severely limits balancing the water budget. Satellite data have the potential to quantify the water budget with spatially consistent data. However, the task is very challenging. Precipitation was highly overestimated and large uncertainties occurred in other individual budget components over the Mississippi River basin. Irrigation, a form of agricultural management practices, has a substantial impact on the water cycle by increasing evapotranspiration 100 W m^{-2} and reducing an equivalent amount of sensible heat flux over many regions in the continental United States. In areas of forest canopy, evapotranspiration is difficult to estimate from satellite data. Initialization of coupled land-atmosphere models with soil moisture markedly improved the skill of predicting precipitation over North America up to 45 days in advance, indicating a strong rationale for NASA's SMAP mission planned for launch in 2014. NASA supports development of global soil moisture algorithms using microwave measurements.

NASA is developing estimates of surface and subsurface (or aquifer) water storage variations, which are important components of the terrestrial water budget and which heretofore have large uncertainty because of the absence of adequate measurements. For northwest India, including New Delhi, 18 km^3/yr of groundwater was depleted from 2002 to 2008 for a net loss of 109 km^3

of water, which was double the capacity of India's largest surface reservoir. In the northeast Indian subcontinent, from Dhaka to New Delhi to Kabul, the groundwater depletion rate was 54 km^3/yr from 2002 to 2008, which could have contributed 0.16 mm/yr to global sea-level rise. The observed intensity of the 2005 extreme drought in the Amazon River basin, which was called a "public calamity," was much greater than that estimated by data-assimilating climate and land-surface models. For regional scales of about 650 km x 650 km, a new method for estimating variations of groundwater storage was successfully tested for the U.S. High Plains Aquifer.

Sea surface temperature (SST) is a critical precursor of weather because of the important exchange of heat between the atmosphere and ocean. Several satellites carrying infrared- and microwave-sensing instruments record SST; microwave instruments "see" through clouds while infrared instruments do not, but data from infrared instruments have a smaller footprint yielding additional information of SST gradients. An innovative uniform SST data product with consistent estimates of measurement error has been developed that integrates SST measurements from nine satellites, each with its own instrument errors and sampling characteristics; the technique is used operationally for weather forecasts and warnings.

The SST is a leading indicator, sometimes 12 months in advance, of wet (potential for flood) and dry (potential for drought) conditions in the continental United States. A cold (warm) Pacific reduces (enhances) precipitation over the continental United States, and this pattern is intensified when the Atlantic and Pacific SST variations are opposite; i.e., a cold Pacific and a warm Atlantic. For dry summers over the continental United States, a cold Pacific produces increased surface air temperature compared to a warm Pacific. El Nino, a warm eastern equatorial Pacific, produces drought conditions in Washington, Oregon, and northern California and flood conditions in southern California and the northern Great Plains. El Nino and La Nina influence the preferred cyclone-track latitudes with El Nino (La Nina) inducing an equatorward and eastward (poleward and westward) shift of the Pacific storm track.

Land snow is an important element of the global water cycle and the occurrence or non-occurrence of land snow cover is a significant ingredient in climate models because the surface reflectivity of incoming solar radiation is very different for snow and land surfaces. A new daily global snow cover data product, including information on the onset of melting, has been developed with a combination of AMSR-E measurements, which are not influenced by clouds and darkness, and MODIS measurements, which have a higher spatial resolution than AMSR-E data but are degraded by clouds. MODIS snow-cover data are useful to predict stream discharge. High-spatial resolution airborne scatterometer backscatter measurements enabled confirmation of coarse-resolution QuikSCAT measurements of snow-water equivalent accumulation in areas of short vegetation, e.g., pasture and sagebrush.

Occurrences of large hail (~20 mm in diameter) are correlated with satellite measurements of very low passive microwave brightness temperatures, which is the foundation for developing a quantitative large-hail forecast method. Over the central and eastern United States, large hail was common when TMI brightness temperatures were below 70°K at 85 GHz, 180°K at 37 GHz and 230°K at 19 GHz.

Lightning is a significant source of concern for public safety and a wide range of weather sensitive operations, including launch and landing of the Space Shuttle. New lightning forecast

methodologies were produced from strong relationships between lightning flash rates and hydrometer microphysical properties observed by the LIS and PR instruments on TRMM.

Clear-sky data from NASA's AIRS instrument have been shown to improve the operational numerical weather prediction (NWP) forecast skill of global weather, including hurricanes. Use of data only in regions unaffected by clouds limits the skill of an NWP system because of discontinuous coverage and because cloudy regions are likely to be more dynamically active. Now, AIRS data in partial cloudy conditions can be used to significantly improve the forecast skill of a tropical cyclone path.

The dynamics of the atmosphere and processes causing rapid (less than 24 hours) intensification of a tropical depression to tropical storm to hurricanes are not well understood. In August-September 2010, NASA conducted the Genesis and Rapid Intensification Processes (GRIP) field campaign in the Atlantic and Gulf of Mexico to learn why a tropical storm forms and strengthen into a hurricane. Innovative instruments will, for the first time, record detailed atmospheric measurements through the tropical storm or hurricane for 20 hours by NASA's Global Hawk UAS flying above the disturbance while additional atmospheric measurements will be taken at different heights for 4-5 hours within the disturbance with NASA's DC-8 and WB-57 aircraft. The TRMM, CloudSat, and Aura satellites will provide complementary measurements over a wide region. GRIP is coordinated with the National Science Foundation's Pre-Depression Investigation of Cloud-systems in the Tropics (PREDICT) mission with one aircraft and NOAA's Intensity Forecast Experiment (IFEX) field campaign with two aircraft. A single storm could be observed simultaneously by as many as six airborne systems.

Downscaling global models with mesoscale models is a technique to produce regional results. AIRS data improved the skill of 6-hour mesoscale precipitation forecasts by 7 percent compared to a model-forecast system without AIRS measurements. Downscaling is achieved with convection-allowing, 4-km grid-spacing models that explicitly discriminate between different mesoscale modes of convective overturning. The CloudSat CALIPSO Validation Project in January 2007 along the United States – Canada border yielded an abundance of excellent data to improve the parameterization schemes for snow crystals and profiles of ice and water content in weather research and forecast models.

Global Carbon Cycle. The distribution of natural carbon among atmosphere, land, ocean, and ecosystems is a daunting challenge because carbon reservoirs are large and carbon fluxes or exchanges between reservoirs, while not large, are extremely important and difficult to measure. The challenge is made more complicated by emission of anthropogenic carbon by human intervention and environmental changes that affect the carbon cycle on an unprecedented scale.

NASA's goal is to quantify changes in atmospheric carbon dioxide and methane concentrations and terrestrial and aquatic carbon storage in response to fossil fuel combustion, land-use, and land-cover changes, and other human activities and natural events. Improved understanding of the interwoven spatial and temporal scales of a myriad of processes occurring within the atmospheric, terrestrial, and aquatic carbon reservoirs and among their interactions will lead to more accurate predictions of phenomena; such as, harmful algal blooms, invasions by exotic species, and production changes in forest and agricultural systems. Potentially, climate projections of carbon throughout the global integrated Earth system could extend 50 to 100 years

into the future. Carbon in the atmosphere was described above; carbon in terrestrial and aquatic regimes is described below.

NASA observations contribute to detection and quantification of environmental, social, economic, and human health consequences of current and potential land-use and land-cover change (LULCC) in the Arctic, tropics, boreal forests, drylands, coastal zone, mountains, and temperate forests. LULCC research addresses the following questions: where are land cover and land use changing, what is the extent, and over what time scale; what are the causes and what are the consequences of LULCC; what are the projected changes of LULCC and their potential impacts; and, what are the impacts of climate variability and changes on LULCC and what is the potential feedback?

Global forest cover, which is an important ingredient in carbon monitoring, is declining. MODIS and Landsat data indicated that the global forest cover in 2005 was 3.1 percent smaller compared to 2000; the boreal biome experienced the largest loss (4 percent) of four biomes and the United States had the largest single-country loss of 6.0 percent.

Agricultural lands have potential to sequester carbon, although emissions of carbon dioxide through use of fossil fuels in planting, harvesting, weed and pest control, and manufacture and transport of soil amendments; e.g., fertilizers, pesticides, and lime, may alter the net soil absorption or release of carbon dioxide. Adoption of conservation tillage practices in the United States from 1990 to 2004 yielded an annual net reduction in fossil fuel carbon dioxide emissions when agricultural policy decisions, weather events, and commodity prices influenced energy usage and cropland production; e.g., the 1993 flood and the 1996 Farm Bill. The high-spatial resolution of NASA's MODIS instruments on the Aqua and Terra satellites provides opportunities to develop carbon accounting methods from field- to national-scales. In 2004, many 1-km x 1-km cropland areas in the United States had agricultural fossil fuel emission greater than the amount of carbon accumulated in the soil; i.e., cropland was a net source of carbon dioxide to the atmosphere. The MODIS 250-m median crop probability data product has proved a sensitive global indicator of broadleaf crops; such as, corn and soybeans, and less sensitive for wheat and rice.

National and state parks and other protected areas are valuable locations to test satellite instrument algorithms and to study natural variations in landscape ecology because these areas are, to a large extent, not impacted by society. In the northeastern United States, increased urbanization of areas connected to parks and protected areas complicate efforts to preserve intact functional ecosystems in existing parks and protected areas because of the important loss of habitat areas, which would further isolate habitat islands and increase the likelihood of local species extinctions and loss of biodiversity. The 4-6°C warming and no change in precipitation predicted at Yosemite National Park by 2100 are expected to produce reduced winter snowpack and an earlier onset of the growing season, resulting in prolonged drought and reduced vegetation productivity. In contrast to parks and protected areas, the influence of human activities on natural landscapes is rapidly expanding throughout the conterminous United States, increasing from 9 percent from 1992 to 2001 to a projected 12 percent from 2001 to 2030.

The collapse of the Soviet Union and allied countries in 1989-1991 triggered the most widespread and abrupt episode of land change in the twentieth century, with large tracts of

cultivated land being abandoned and reverting gradually to grassland. Landsat data showed the substantial increase in private-forest use; e.g., logging and cultivation, compared to national-park-forest use. Aqua and Terra MODIS data recorded over Kazakhstan, where an extreme government-enforced LULCC occurred in the middle of the 20th century, when 13 million hectares of native steppe were converted to wheat production in a dozen years, showed that the decreasing trend in vegetation was due to both agricultural abandonment and drought.

LULCC influences the global carbon and nitrogen cycles. For example, nitrogen dynamics impact the re-growth of secondary forests, and nitrogen deposition influences terrestrial carbon uptake. A modeling study of the global carbon-nitrogen cycle showed that LULCC over the 1900-2000 period produced constant annual soil carbon stocks and a substantial decrease in annual vegetation carbon stocks. Nitrogen limitation substantially reduces the global amount of secondary forest carbon sink, perhaps by 150 percent of estimates made without nitrogen limitation.

Forests cover 40 percent of Earth's ice-free land surface and are the focus of intense research in global environmental change; tropical forests contain 40 percent of Earth's forested biomass. A major source of error in estimates of land surface carbon and other biogeochemical fluxes arises from uncertainty in prescribing initial forest carbon stocks, and subsequent changes to these from growth, degradation, and deforestation. New remote sensing technologies have the potential to quantify stocks, sources, and sinks of land surface carbon. In preparation for the Decadal Survey DESDynI and ICESat-II missions, which have the potential to provide unprecedented global data on vegetation structure, airborne measurements were made of vegetation's 3-dimensional structure, biomass, and disturbance. Airborne lidar measurements over the La Selva tropical forest in Costa Rica in 1998 and 2005 showed that the height of old-growth forests decreased by 0.3 m while the height of secondary forests increased by 2.1 m; the old-growth and secondary forest biomasses remained constant within 2 Mg/ha and increased significantly by 25 Mg/ha, respectively. Airborne interferometric synthetic aperture radar (InSAR) and lidar measurements produced comparable results at La Selva for the canopy height mean and spatial variations. ICESat lidar forest-height measurements in 2003, combined with Landsat forest-disturbance data since 1984, revealed that young, recovering forest heights in Mississippi, Virginia, and Maine increased about 1.2, 1.0 and 0.63 m yr^{-1}, respectively.

DESDynI's integrated InSAR and lidar measurements will represent a breakthrough for advancing forecast models for terrestrial carbon stocks and fluxes. Present large-scale global carbon models do not have the level of detail and resolution to capture relevant terrestrial heterogeneity and, thus, are deficient on the role of disturbance/recovery in the global carbon balance; i.e., errors in initialization lead to prediction error. A robust model-data framework will require both models and data on vegetation structure to resolve 1-ha environmental gradients and tree-level heterogeneity in forest structure globally.

Terrestrial ecosystems sequester carbon dioxide and are a major sink in the global carbon cycle, slowing the rate of increasing carbon dioxide concentration in the atmosphere. From 1982 to 1999, the increasing temperature and carbon dioxide in the atmosphere provided excellent conditions for an upward trend in the amount of atmospheric carbon dioxide absorbed by terrestrial plants. However, this trend did not continue in 2000-2009, which was the warmest decade since instrumental observations began in the 1880's. A warming climate lengthened the

growing season, promoting plant grow, but a warming climate also produced large-scale droughts that reduced regional uptake of atmospheric carbon dioxide, weakening the terrestrial carbon sink. In high latitudes, the carbon cycle on long time scales is more complicated. On decadal time scales both carbon dioxide fertilization and warming-enhanced vegetation growth produced a sink for atmospheric carbon dioxide, but on centennial time scales under intense warming, increased decomposition of soil organic matter may release additional carbon dioxide, causing vegetation to be a net source.

Wetlands are major sinks and sources of atmospheric greenhouse gases and can switch between atmospheric sink and source in response to climatic and anthropogenic forcings. Despite their importance in the global carbon cycle, the locations, types, and extents of wetlands is poorly known because of the absence of adequate observations. A first-ever high-resolution thematic map of wetlands throughout Alaska, developed with SAR data from the JAXA JERS-1 mission, proved 89 percent accurate, which can be used to estimate wetlands-atmosphere fluxes of carbon dioxide and methane.

Marine phytoplankton abundance is the foundation of the oceanic food web and affects diversity of organisms, drives ecosystem functioning, impacts fishery yields, controls atmospheric carbon dioxide levels through photosynthetic carbon fixation, and impacts climate variability and change. NASA initiated satellite measurements of phytoplankton in 1978-1985 and has continued the measurements since 1997. Multi-decadal variations in global and regional phytoplankton abundances are related to basin-scale ocean oscillations; e.g., the Pacific Decadal Oscillation, El Nino, and La Nina. Estimating a long-term global trend with satellite data is a formidable challenge because of the relative shortness of the record coupled with high-amplitude daily-seasonal-to-interannual variations. In a hundred-year in-situ data record, global phytoplankton decreased about 1 percent of the median value per year because increasing stratification (caused by increasing sea surface temperature) limited the upwelling of nutrients to the euphotic zone. An abrupt centennial-scale biogeochemical regime shift occurred nearly 200 years when an expansion of subsurface nutrient-rich water occurred off Peru resulting in present-day biological productivity, including pelagic fish.

Satellites record oceanographic data independent of the fury of the ocean, which prevents oceanographic research vessels from taking observations in high winds and waves, such as during autumn and winter in middle latitudes. Nine years of satellite ocean color measurements of chlorophyll data upended the traditional critical-depth hypothesis of how and why a phytoplankton bloom occurs in the mid-latitude ocean. SeaWiFS observations revealed a surge in phytoplankton abundance during winter, which occurs long before increases in sunlight and mixed layer depth would have an influence on phytoplankton growth. The old theory was solely physically based, relying on sunlight and mixed layer dynamics, while the new idea incorporates both biology; i.e., zooplankton that eat phytoplankton and physics of mixed layer deepening with solar radiation to explain the observations. In eastern boundary wind-driven upwelling ecosystems, physical dynamics have a strong controlling influence on development of phytoplankton blooms.

NASA conducted the ocean ICESCAPE (Impacts of Climate on Ecosystems and Chemistry of the Arctic Pacific Environment) expedition on the USCGC *Healy* in June-July 2010 to understand the biogeochemistry and ecology in the western Arctic Ocean. The *Healy* operated in

ice-free and ice-covered regions. Above- and in-water bio-optical measurements were made for vicarious calibration of data from SeaWiFS and MODIS instruments. Ice cores were taken to measure oxygen isotopes and the amount of algae growing on the bottom of sea ice. The vertical distribution of sunlight through the ice was measured for different ice surface, thicknesses, and surface-melt conditions. The interdisciplinary suite of biological, chemical, and physical oceanographic measurements revealed that ocean current horizontal advection of nutrient-rich water strongly contributed to the increase in primary production, which has been observed in NASA satellite data recorded on the continental shelf of the western Arctic when sea ice cover waned. Without a global-warming-produced ice-free summertime ocean, sunlight and nutrients would not produce phytoplankton. The source of the nutrient-rich water is a subject of continuing study. The second ICESCAPE expedition is planned for August-September 2011 in the same region with the USCGC *Healy*.

Major elements of a U.S. carbon cycle observation system require observations from satellites; in-situ observations of land, ocean, and aquatic systems; and direct atmospheric measurements, all of which have gaps and are threatened with widening gaps. Another challenge is the shortness of the satellite time series, which, in the case of a greenness vegetation index, could be extended into the past. In FY 2010, NASA began developing a Carbon Monitoring System (CMS), which, in an initial pilot phase, would replicate state and national carbon and biomass inventory processes. Initially, in 2010-2011, CMS will have three foci: (1) quantify above-ground vegetation carbon stock in the United States, with subsequent plans for extension to a global product; (2) develop a global data product for integrated emission and uptake or flux of carbon dioxide between the atmosphere, land, and oceans; and (3) develop capabilities to enhance carbon-related information products from future research efforts and planned observation capabilities to aid decision makers.

United States Geological Survey (USGS)

The 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 U.S. 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.

Glacier Monitoring. 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. The USGS, in cooperation with Bureau of Land Management (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.

EMERGENCY RESPONSE AND HOMELAND SECURITY SERVICES

For purposes of this *Federal Plan*, Emergency Response and Homeland Security Services are those specialized meteorological services and facilities established to meet the requirements of Federal, state, and local agencies responding to natural disasters and security incidents. This category includes the use of atmospheric transport and diffusion (ATD) models for predicting the dispersion of airborne toxic substances; it also includes natural disaster monitoring and prediction services and the transport of water-borne toxic substances not included in basic services. For example, numerical weather prediction models used to forecast the path, intensity, and storm surge of landfalling tropical cyclones are part of basic services. Downstream models of the effects of a landfalling tropical cyclone on the infrastructure and population of a particular populated area could be included in this service category.

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

Federal Emergency Management Agency (FEMA)

FEMA's interagency collaboration and support is key to disaster impact assessments and plans.

FEMA's mission is to support U.S. citizens and first responders to ensure that as a Nation we work together to build, sustain, and improve our capability to prepare for, protect against, respond to, recover from, and mitigate all hazards. 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, which 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 (NWS/NHC). These studies are used by state and local hurricane emergency management planners and decision makers to develop their hurricane evacuations plans.

It is critical for FEMA to identify, develop, and/or utilize 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 actively supports the OFCM-sponsored Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (WG/DIAP) and the WG/DIAP's efforts to develop an implement the National Plan for Disaster Impact Assessments which outlines the interagency procedures 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.

Interagency Modeling and Atmospheric Assessment Center

Under the National Response Framework, the mission of the Interagency Modeling and Atmospheric Assessment Center (IMAAC) is to provide a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position during an actual or potential incident. The IMAAC provides plume modeling analyses of the impacts of hazardous atmospheric releases to aid in protecting the public and the environment.

The IMAAC is led by the Department of Homeland Security and supported by seven other Federal departments and agencies: Department of Defense, Department of Energy (DOE), Department of Health and Human Services, Environmental Protection Agency, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration (NOAA), and Nuclear Regulatory Commission. The DOE's National Atmospheric Release Advisory Center at Lawrence Livermore National Laboratory serves as the operations hub of the IMAAC.

Decision makers and first responders need timely and accurate plume predictions to help guide emergency response decisions. The IMAAC provides a suite of plume modeling tools that incorporate meteorological, geographic, and demographic data, as well as hazardous material information, to predict the transport and potential downwind consequences of biological, chemical, radiological/nuclear, and natural releases. The IMAAC experts are available 24/7 to produce detailed quality-assured model predictions, utilize observations and field measurement data to refine analyses, and assist decision makers in product interpretation.

The IMAAC produces both technical analyses and briefing products tailored for communications to non-technical decision makers. IMAAC plots and consequence reports show hazard areas,

affected populations, potential casualties and/or fatalities, and damage estimates, as well as levels of health effects, public protective action, and worker protection. The IMAAC utilizes NOAA National Weather Service's (NWS) meteorological observations and designated preferred model forecasts for the plume models. The IMAAC may also use an in-house higher-resolution forecast model if determined to be representative or if IMAAC does not have access to the preferred forecast data.

The IMAAC has responded to numerous real-world events, including chemical fires and train derailments, in-situ burns from the Deepwater Horizon oil spill, and sulfur dioxide volcanic emissions in Hawaii.

NOAA NWS

National Tsunami Hazard Mitigation Program (NTHMP). In FY 2004, NWS assumed operational responsibility for the NTHMP, the goal of which is to ensure adequate advance warning of tsunamis along all U.S. coastal areas and appropriate community emergency response to a tsunami event. In response to the destructive Indian Ocean Tsunami, the U.S. Tsunami Warning Program, including the NTHMP, was upgraded and expanded to enhance the monitoring, detection, warning, and communications capabilities designed to protect lives and property for all U.S. communities at risk.

NOAA Weather Radio (NWR). NWR is used as a reliable, inexpensive means of communicating weather related warnings directly to the public.

Interagency Activities. 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. In addition, NWS forecasters provide forecasts in response to Incidents of National Significance such as the space shuttle Columbia recovery effort, Hurricane Katrina, and the Greensburg, Kansas, tornado response.

The NWS deploys a national cadre of specially trained Incident Meteorologists (IMETs) 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.

NOAA National Ocean Service (NOS)

Coastal Oceanographic Applications and Services for Tides and Lakes (COASTAL). The COASTAL program focuses on non-navigational applications of observing systems, data, and products for ecosystem restoration and management at the Center for Operational Oceanographic Products and Services (CO-OPS). COASTAL also provides decision support tools to aid managers and restoration practitioners in planning for both current and future coastal conditions and to anticipate and mitigate natural hazards. Real-time water level and meteorological information is critical for emergency managers to make decisions related to evacuation and warnings for coastal communities as well as to produce storm surge predictions.

The Storm QuickLook (and most recently Oil Spill QuickLook) product in particular incorporates water level and meteorological information measured at stations of the National

Water Level Observation Network (NWLON) and Physical Oceanographic Real-Time System (PORTS®). (For more description of NWLON and PORTS, see "Surface Transportation Services," "Operational Programs.") Storm QuickLook bulletins are posted for tropical cyclones that affect the U.S. coastline. The Oil Spill QuickLooks were posted for the duration of the Gulf Oil Spill. These bulletins, which provided near-real-time oceanographic and meteorological data measured at affected water-level stations, was displayed on the CO-OPS website and on the NOAAWatch (The NOAA All-Hazard Monitor) webpage. FY 2011 goals for these products include enhancing the displays and making the products more dynamic. Also, 6-minute interval Geostationary Operational Environmental Satellite (GOES) transmission capability supports the NWS storm surge warning program when expected water level elevations are predicted or observed during coastal storms and hurricanes.

NOAA Office of Marine and Aviation Operations (OMAO)

Among the NOAA/OMAO airborne observing systems fleet, the King Air (N68RF) and AC-695A Commander 1000 (N45RF) aircraft perform post-storm damage assessment flights, following natural disasters from landfalling tropical storms. They provide high-resolution photographs of the storm-induced damage, which are available to the public via the Internet. These photographs are extremely useful to local, county and state government personnel, as well as to emergency managers and to the public at large, as they go about the business of assessing the damage and the nature and magnitude of the relief effort that will be required in the region affected by the storm.

Department of Energy

Meteorological Services at DOE Facilities

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 operational and research-driven 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, and reinforced by several DOE Orders, Guides and Handbooks, and national voluntary consensus standards that specify requirements for meteorological services to protect the environment. Consequently, a meteorological monitoring program, of varying complexity, 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).

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 stewardship. 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 forecasted atmospheric transport and diffusion conditions.

DOE administers operational meteorological activities through various offices, such as the Office of Health Safety and Security (HS), the National Nuclear Security Administration (NNSA), and the Office of Environmental Management (EM), that have missions linked to the atmospheric sciences. Activities at DOE sites include support to daily operations (e.g., health and safety of workforce under severe weather conditions) and national defense programs; all of which require fundamentally sound and well-managed meteorological monitoring programs.

Operational Meteorological 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 have been established at Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Idaho National Laboratory (INL), Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Nevada National Security Site (NNSS), Oak Ridge Reservation (ORR) inclusive of Y-12, and Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL) and Hanford Site, Pantex Plant, Sandia National Laboratory—Albuquerque (SNL-AL), Savannah River Site (SRS)/Savannah River National Laboratory, and the Waste Isolation Pilot Plant (WIPP). Some of these DOE sites maintain 24-hour weather watches for severe weather conditions that have the potential to impact 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 NNSS, Hanford, SRS, and INL. The Nevada Site Office, which manages NNSS, 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 reservations (e.g., INL, ORR, NNSS, 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 accurate characterization of the latter is important for their influence 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 (MADIS). Moreover, some DOE sites use the NOAA Advanced Weather Information Processing System (AWIPS), as well as vertical profilers and meteorological monitoring networks.

Nuclear Regulatory Commission (NRC)

At the present time, the NRC is a user of meteorological information rather than a performer of research in this field. Meteorological data are 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 uses 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.

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. All these reviews include consideration of meteorological factors. Employees of these NRC offices also conduct rulemaking activities (?) 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.

U.S. Geological Survey Role in Emergency Response to Natural Hazards

The USGS mission provides for "the classification of the public lands and the examination of the geological structure, mineral resources, and products of the National Domain." The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life. Among its broad responsibilities and efforts are identification, assessment, and monitoring of potentially hazardous areas; development of capabilities to predict the time, place, and the severity of hazardous geologic, hydrometeorologic, biologic, and chemical conditions or events; and dissemination of the

findings and their implications, including the provision of technical and scientific advice to public officials. The USGS also maintains Bureau-wide efforts intended to educate the public about natural hazards.

The USGS has been delegated the Federal responsibility to provide notification and warnings for earthquakes, volcanoes, and landslides. In addition, USGS data-collection networks provide real-time information needed by other agencies to issue forecasts and warnings related to a variety of hazards. For example, the USGS seismic network supports NOAA tsunami warnings; the USGS streamgage network supports NOAA flood forecasts (see Hydrometeorological and Water Resources Services); the USGS geomagnetic observations support solar storm forecasts (see Solar Weather Services); USGS biologic monitoring of wildlife diseases enhances assessments of potential human pathogens such as the H1NI influenza virus; and USGS geospatial and remotely-sensed information supports a broad spectrum of disaster-response activities and operations from an "all-hazards" perspective.

The USGS established a secondary reception station for NOAA GOES at the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD. Three new satellite antennas and an existing antenna at EROS are used in support of this effort. Three of these antennas support communications with the GOES East and GOES West satellites, along with a hot spare. The remaining antenna is designated for a DOMSAT link, which is used for data dissemination. EROS also receives streamgage data in real time from the GOES satellites and is making these data available to USGS and other stakeholders. The receive station at EROS serves as a backup to the primary site [station] at Wallops Island, Virginia, which otherwise would represent a single point of failure in this vital data collection and dissemination system.

Beyond network operations, the USGS has expertise and infrastructure to acquire, assess, disseminate, or preserve information that can be derived from the study of geological, hydrological, meteorological, chemical, or biological conditions before, during, or after an imminent or declared disaster or emergency. These capabilities can be tapped through mission assignments, interagency agreements, or third party contacts, as provided by law and regulation.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NOAA Office of Oceanic and Atmospheric Research, Air Resources Laboratory (ARL)

ARL Headquarters develops and improves dispersion and air quality models, collects research-grade air quality and deposition measurements of select air quality parameters, and provides climate-relevant datasets and assessments of climate variability and trends. Some products developed by ARL augment the operational product suites of the NOAA service-oriented line offices, particularly the NWS. Other products are state-of-the art, web-based assessment tools that serve university researchers, Federal research agencies, and international partners. For instance, ARL continues to improve dispersion tools that provide forecast support to NOAA's emergency response activities with an 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 ARL Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model is operational at NOAA's National Centers for Environmental Prediction (NCEP) and serves as the national

dispersion forecasting capability in several other countries. 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 radioactive plume crosses international boundaries.

ARL also conducts research and development to improve NOAA's operational air quality forecast system. This includes extending the domain covered by operational ozone and wildfire smoke forecasts, improving wind-blown dust prediction capabilities, and working toward a future operational particulate matter prediction.

The ARL Atmospheric Turbulence and Diffusion Division (ATDD) in Oak Ridge, Tennessee, conducts research and development in air quality, climate, and atmospheric dispersion, with an emphasis on understanding and predicting the behavior of the lowest portion of the atmosphere. The main research goals are to develop better methods for predicting transport, dispersion, and air-surface exchange of air pollutants and to improve reference-grade measurement of climate change and related physical and chemical processes.

ARL Headquarters and ATDD jointly conduct world-class research on the atmospheric mercury cycle. While mercury emissions come from a variety of sources and media, the majority of mercury released to the environment occurs as atmospheric emissions. From the atmosphere, mercury is eventually deposited in watersheds and receiving waters, where it can be converted to methylmercury, a highly toxic form, which bioaccumulates in the aquatic food chain leading to the fish used as human and livestock food sources. A cornerstone of ARL's work is a state-of-the-art modeling system that tracks mercury emission sources and links these emissions to atmospheric transport, transformation, and deposition.

ARL also conducts long-term intensive monitoring of mercury in ambient air. Data collected are analyzed to gain useful insights into the origin, transport, and deposition of atmospheric mercury and for interpreting and evaluating ARL's mercury modeling system. ARL's mercury products and services directly support air quality decision-makers, air quality forecasters, and the mercury research community.

The ATDD also operates an intensive urban research meteorological network within the National Capital Region, called DCNet. The network has been in operation since 2003 and consists of 15 stations that collect the standard meteorological parameters (temperature, wind speed, and direction) and also measure characteristics of atmospheric turbulence. DCNet provides critical data and insights that improve predictions of where airborne hazardous materials will go, thereby improving emergency managers' ability to protect first responders and the public. With a strong focus on data quality, DCNet is designed to support development of urban monitoring methodologies and observation standards; evaluation of the utility of using private meteorological observing networks within urban environments; and accumulation of an intensive dataset for model evaluation and initialization, process studies, and decision support. DCNet observations are used by numerous government security and emergency management activities within the National Capital Region.

The ARL Field Research Division (FRD), in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models at local, regional, and continental scales. FRD has also continuously observed and recorded meteorological conditions at the Department of Energy (DOE) Idaho National Laboratory (INL) and its environs since 1948. FRD manages the 35-station NOAA/INL Meteorological Monitoring Network, an observing mesonet that includes advanced hardware and software. This network contributes to the generation of site forecasts and severe weather notices issued for special and routine INL operations. FRD meteorologists staff the DOE Emergency Operations Center during drills and emergencies, such as accidental toxic chemical releases and wildfires.

The ARL Special Operations and Research Division (SORD) in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities. SORD is involved in research related to the desert environment including improvements to the Weather Research and Forecasting (WRF) mesoscale model and research on the climate effects of the El Niño Southern Oscillation.

SORD also participates in two air quality and visibility programs: The Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a Federal land management and Environmental Protection Agency air quality and visibility program focused on measuring particulate matter over the United States. The Rocky Mountain Atmospheric Nitrogen and Sulfur (ROMANS) study is examining increases in nitrogen deposition in the Rocky Mountains.

ARL also participates in national networks that direct research attention on the needs of the next generation of predictive models. One of these is the Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested network with sites of varying complexity addressing 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 systems. A second example is ARL's collaboration with the Global Monitoring Division (GMD) of NOAA's Earth System Research Laboratory (ESRL) in operating the Surface Energy Budget Network (SEBN) as a contribution to NOAA's Climate Observing Systems. SEBN provides a complete set of data that describes the physics of energy exchange and feedbacks at the land-surface interface. Many of these stations are augmented with instrumentation to measure fluxes of sensible heat, latent heat, momentum, and carbon dioxide. SEBN provides valuable information for evaluating and improving the parameterization of the land-atmosphere interface in predictive models.

Department of Energy Meteorological Coordinating Council (DMCC)

The DOE Meteorological Coordinating Council (DMCC) was established 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 management and operating 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 (SCAPA). 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 (SQA) 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 tools to enable DOE/NNSA sites to perform their own self-assessments of its meteorological monitoring program and the meteorological aspects of consequence assessment.

Nuclear Regulatory Commission

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.

The NRC conducts meteorological research to support licensing activities. Current research activities include quantifying the storm surge from severe weather events and updating the hydrometeorological reports (HMRs) and methods used to estimate the effects of extreme precipitation events. This work is prioritized for those areas of the United States where new nuclear power plants are proposed and will provide the design basis for flood protection systems. The work will be done in cooperation with the U.S. Bureau of Reclamation.

HYDROMETEOROLOGY AND WATER RESOURCES SERVICES

For purposes of this *Federal Plan*, Hydrometeorology and Water Resources Services are those specialized meteorological services and facilities that combine atmospheric science, hydrology, and water resources in order to meet the requirements of Federal, state, and local agencies for information on the effects of precipitation events on infrastructure, water supplies, and waterways. These products and services also meet the needs of the general public in the conduct of everyday activities and for the protection of lives and property.

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

National Weather Service Forecast and Warning Services

The National Weather Service (NWS) has the primary responsibility among Federal agencies to provide advanced alerts via flood warnings and forecasts in the United States. The 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), and the National Centers for Environmental Prediction's (NCEP) Hydrometeorological Prediction Center (HPC) and Climate Prediction Center (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. The WFOs work collaboratively with the RFCs to monitor hydrologic conditions around the clock. Using RFC guidance, Doppler weather radar (NEXRAD), and telemetered rain gauge observations, the WFOs continuously monitor the threat of flash flooding and urban flooding to provide timely flood watches and warnings.

River and flood forecast services are provided in the form of daily river forecasts by the 13 RFCs, using hydrologic models based on rainfall, soil characteristics, precipitation forecasts, and several other variables. Some RFCs, especially those in mountainous regions, also provide seasonal snow pack and peak flow forecasts. These forecasts are used by a wide range of users, including those in agriculture, hydroelectric dam operation, and water supply resources. The information is also the basis for local flood and flash flood warnings, watches, and advisories issued by the WFOs that emphasize flooding impacts, depending on geographic area, land use, time of the year, and other factors.

The HPC, located in Camp Springs, Maryland, is responsible for preparing quantitative precipitation forecasts (QPFs), which are used by WFOs to develop local rainfall, snow, and ice forecasts and by the RFCs to develop local river and flood forecasts. The HPC provides special QPFs and coordinates with other Federal agencies; such as, the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of analysis products and forecasts of frontal systems, pressure patterns, temperature, and precipitation for use by the WFOs and the private-sector weather services community.

Water resource forecast services extend basic NWS hydrologic forecasting services to include a Community Hydrologic Prediction System (CHPS) and provide water resource managers with localized water and soil condition forecasts. CHPS will be fully operational by FY 2012, and Water resource forecast services will be provided for 7 percent of the Nation by that time. It will serve as the backbone for NOAA's national water information strategy, allowing NOAA's research and development enterprise and operational service delivery infrastructure to be integrated and leveraged with other Federal water agency activities and the private sector. Through CHPS, NOAA will deliver a new suite of high-resolution forecasts (including estimates of uncertainty) for stream flow, soil moisture, soil temperature, and many other variables directly related to watershed conditions, via collaboration and sharing of data and algorithms with university and private sector research groups. Furthermore, these activities will enable NOAA to deliver a national database of hydrologic analyses and predictions and generate user-friendly geographic information system (GIS) products for monitoring floods and drought. This activity contributes to the National Integrated Drought Information System (NIDIS).

Advanced Hydrologic Prediction Service (AHPS). The NWS continues to implement AHPS to provide hydrologic forecasts with lead times ranging from minutes to months. AHPS builds on the existing NWS infrastructure, including the Advanced Weather Information Processing System (AWIPS), NEXRAD, and the NWS River Forecast System. 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. 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. Flash floods, typically caused by intense, small-scale convective systems, are the leading cause of flood fatalities. 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 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., the National Ocean Service and the Office of Oceanic and Atmospheric Research [OAR]).

Integrated Water Forecasting. NOAA's Integrated Water Forecasting activity is being implemented to build on AHPS and other NOAA water forecasting services to deliver new information from the summit to the sea at higher resolutions (down to the neighborhood scale). The new information includes: coupled river, estuary, and lake forecasts; soil moisture; soil temperature; snow pack; and surface runoff volume. These services will enable NOAA to provide nationally consistent gridded forecasts of water quantity and quality via a national digital database that assimilates hydrometeorological data and a community hydrologic modeling system, which brings the current state of science to NOAA 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 its partners and other users.

NWS Partnerships for Hydrometeorological Products and Services. 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 on water-related issues with the U.S. Geological Survey (USGS), U.S. Bureau of Reclamation, and Bureau of Land Management in the Department of the Interior; with the U.S. Army Corps of Engineers (USACE) in the Department of Defense; with the Department of Agriculture's Natural Resources Conservation Service (NRCS); and with the Department of Homeland Security (DHS). Among these partnering activities are stream gaging, support for flood mitigation activities including flood inundation mapping, river and water supply forecasting, and water management. For example, river stage observations and stage discharge relationships provided by the USGS are critical to warning and forecast operations for the Nation's rivers.

USGS Hydrometeorological Data Collection and Distribution

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 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 NWS RFCs for river forecast points. Additional historical and real-time water resources data are available from the USGS database at NWIS Web (http://waterdata.usgs.gov/ nwis/). During floods, these data are supplemented by additional flood flow measurements. For example, during the 2009 floods of the Red, Minnesota, Missouri, and James River basins, the USGS made over 1,200 streamflow measurements at more than 150 streamgages and installed Rapid Deployment Gages at 15 locations, all in support of flood forecasting and (or) emergency operations. At the request of the NWS and the U.S. Army Corps of Engineers, the USGS collected 28 special discharge measurements at the James River

The USGS has developed new rapidly deployable, mobile streamgages to provide short-term water-level data to critical areas lacking permanent streamgages. Image provided by USGS Office of Surface Water.

above Arrowhead Lake near Kensal, North Dakota, in order to define the flow going into the Jamestown Reservoir.

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.

NRCS Hydrometeorological Observations

Since snowmelt provides 50-80%t of the water supply in the Western United States, having information on snowpack is critical for water management. The NRCS measures snowpack and collects hydrometeorological data in the 12 western states. Through the Snow Survey and Water Supply Forecasting Program (SSWSF), the NRCS conducts snow surveys at high elevations in the mountainous West. The data collection system includes approximately 950 active manual snow courses and 790 automated SNOTEL (SNOw pack TELemetry) monitoring stations. NRCS collects data at the manual snow courses in cooperation and often with assistance from a number of different Federal, state, local and private partners. These data, along with information from 660 stream gages, 328 major reservoirs, and approximately 3,200 climatological observation stations managed by other agencies, are merged into a hydroclimatic database that is used to produce real-time watershed analyses and water supply forecasts. This information is used from the farm level (e.g., to manage irrigation) up to the international level as the basis for water management decisions under treaties with Canada and Mexico.

The SNOTEL automated data collection system provides near-real-time remote hydrometeorological data that significantly improve flood stage forecasts and the monitoring of other life-threatening snow-related events. The primary use of the Snow Survey data is the production of water supply forecasts for approximately 740 western basins. The data are also used by irrigators, recreation users, researchers, Federal and state agencies, and a multitude of others. All SNOTEL data is sent hourly to the NWS to assist in forecasting flood events. SNOTEL information enables emergency management agencies to effectively mitigate drought and flood damages and to monitor and assess forest and wildfire potential.

Monthly water supply forecasts are produced each year from January through June in partnership with the NWS. 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 this joint NWS-NRCS effort. The purposes of water supply forecasts are to: (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) operate reservoirs to satisfy multiple use demands including hydropower generation; (6) mitigate flood damages in levied areas and downstream from reservoirs; and (7) support fish and wildlife management activities associated with species protection legislation.

The NRCS develops seasonal water supply forecasts for 740 locations in 12 western states. In addition, the program provides daily water supply guidance forecasts for 138 western basins.

During the 2009–2010 season, the NRCS produced approximately 6,540 official forecasts and nearly that many interim guidance forecasts. These product provides information for water managers to adapt to weather changes as they occur. The web link for this information is http://www.wcc.nrcs.usda.gov/wsf/daily_forecasts.html.

Historical snow survey data is valuable to climate change researchers and in developing reliable projections of climate change. It is projected that changes to the hydrologic cycle in the western states resulting from changes in snow pack will increase the water supply challenges these states face. The current monitoring data will help water managers at all levels adapt to climate change impacts.

The SSWSF Program provides a variety of climate and water supply products that are used to assess Western drought (Figure 4). These include SNOTEL snowpack and precipitation analyses in the mountains, water supply forecasts, and State Surface Water Supply Indexes (SWSI). These products are critical to the weekly production of the interagency Drought Monitor, a web-based report. Separate from the SSWSF and SNOTEL network, the NRCS also manages a cooperative nationwide network of approximately 175 Soil Climate Analysis Network (SCAN) sites in 40 States and U.S. territories monitoring soil temperatures and soil moisture. These data are used to support national drought monitoring, production agriculture, and climate change research.

NOAA Office of Marine and Aviation Operations (OMAO)

Within the NOAA/OMAO aircraft fleet, a NOAA AC-695A Commander 1000 (N45RF) and a NOAA AC-500 Shrike (N51RF) aircraft are used annually to conduct important snow pack surveys in the northern and western continental United States, 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. The data are transmitted to the National Operational Hydrologic Remote Sensing Center (NOHRSC) up to three times a day from each aircraft. After further processing, but within 5 minutes of receipt from the survey aircraft, the data are distributed to NWS WFOs, RFCs, and other centers. The processed 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.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NOAA Office of Oceanic and Atmospheric Research

Hydrometeorological Testbed (HMT). The HMT is a national program aimed at accelerating the infusion of new technologies, models, and scientific results from the research community into daily forecasting operations of the NWS and its RFCs. Research at the HMT has focused on improving regional precipitation forecasts, particularly for heavy, flooding rains. Unlike typical research field projects, the HMT operates as an end-to-end demonstration project with forecasters and researchers joining forces in the operational setting. Through NOAA funding, HMT will provide a foundation level of effort and infrastructure each year in a particular test region. It is expected that this foundation will be augmented by occasional ramping up to more intensive field programs that include additional participants and specialized instrumentation.

The first regional implementation of HMT, called HMT-West, targets California's flood-vulnerable American River Basin. The two biggest water cycle challenges being addressed in HMT-West are QPFS and quantitative precipitation estimation (QPE). In 2010, HMT-West joined forces with the California Energy Commission and California universities to carry out the CALWATER study, which has two primary focus areas: the impact of atmospheric rivers (narrow regions of enhanced water vapor transport in winter storms) on California's precipitation and the impact of anthropogenic air pollution on the amount and distribution of precipitation. Both of these issues need to be addressed in reference to a changing climate. OAR's Earth System Research Laboratory (ESRL) Global Systems Division (GSD) is the lead laboratory for HMT-West. ESRL/GSD and the ESRL Physical Sciences Division (PSD) are partnering to provide an HMT legacy capability in California through support from the California Department of Water Resources.

Beyond 2010, if there is sufficient funding within NOAA to support it, HMT will spin up a second regional implementation in the southeastern United States.

MILITARY SERVICES

For purposes of this *Federal Plan*, Military Services are those meteorological operations, services, and capabilities established to meet the unique requirements of military user commands and their component elements. Programs and services that are not uniquely military in nature are reported under another service category (e.g., Basic Services, Aviation Services [civilian], Surface transportation Services, or Emergency Response and Homeland Security Services).

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

For each of the military services with meteorological operational programs (U.S. Air Force, Navy, Army, and Marine Corps), the discussion below first describes that service's operational organizations, followed by description of the principal meteorological products and services provided by these organizations.

U.S. Air Force (USAF)

Operational Organizations

Air Force Weather

Air Force Weather (AFW) 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. However, most of the weather airmen and civilians who constitute AFW personnel are assigned to and report through the Air Force commands they support. The Director of Weather oversees USAF-wide training, organizing, and equipping of AFW forces and organizations. AFW forces provide mission-tailored terrestrial and space environment observations, forecasts, and services to the Air Force, U.S. Army (USA), and a variety of U.S. government departments and agencies. AFW enables joint warfighters to anticipate and exploit the weather—for air, space, cyberspace, and ground operations.

AFW operations provide a total force capability employing over 4,100 active duty and Reserve Component military and civilian personnel. Airmen in the Weather (15WX) career field act as "eyes forward" to collect, analyze, tailor, integrate, and disseminate weather environmental information, including forecasts of future conditions, in support of military operations. Weather airmen and civilians support USAF and USA conventional forces and Special Operations Forces (SOF) worldwide. The majority of these AFW personnel are focused on two distinct yet related functions: (1) characterizing the past, current, and future state of the natural environment; and (2) exploiting environmental information to provide actionable environmental impacts information directly to decisionmakers.

The AFW support infrastructure is designed to readily deploy and operate in austere expeditionary environments. It is capable of providing sustained, comprehensive, and relevant weather support to all elements of an Air Expeditionary Force, as well as forward deployed air bases and stations of the establishment supporting that force. AFW is organized in a 3-tier structure to maximize capabilities that can be accomplished in the rear area via "reachback" 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.

Further AFW organizational information can be found at:
http://www.afweather.af.mil/index.asp.

Air Force Weather Agency (AFWA)

AFWA is a Field Operating Agency reporting to the USAF Director of Weather. It is the weather production center of the USAF in the *first tier* of the AFW organizational structure. The AFWA weather center delivers worldwide weather products to Air Force and Army warfighters, unified commands, National Programs, and the National Command Authorities. AFWA supplies weather products, training tools, and fields equipment to USAF Operational Weather Squadrons (OWSs) and Weather Flights and provides 24-hour technical assistance on all standard weather systems and equipment. AFWA builds and maintains the world's most comprehensive weather database of observation, forecast, climatological, and space weather products available on the Worldwide Web.

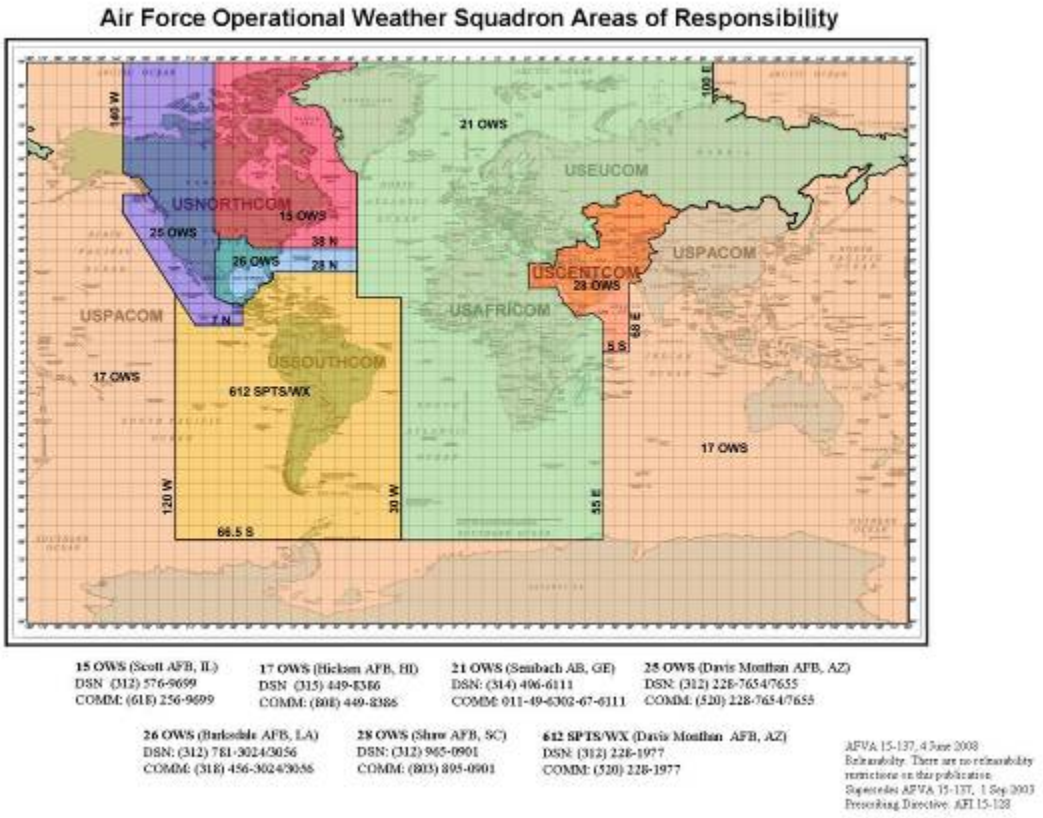
- The 1st Weather Group aligns stateside weather operations with the USAF warfighting initiative overseeing the Operational Weather Squadrons. The 1 WXG has three subordinate OWSs whose areas of responsibility are within the continental United States: the 15th, 25th, and 26th Operational Weather Squadrons. They form the backbone of regionally focused, "reachback" weather operations for the continental United States, providing a variety of weather forecast products and support to units assigned to and/or deployed in their respective areas of responsibility.
- The 2nd Weather Group delivers timely, relevant, and specialized terrestrial, space, and climatological global environmental intelligence to Joint warfighters, U.S. Department of Defense (DOD) decisionmakers, national agencies, and allied nations for the planning and execution of missions across the complete spectrum of military operations through the operation, sustainment and maintenance of AFW's $277 million strategic center computer complex, production network, and applications.

Operational Weather Squadrons

Around the world, OWSs are the *second tier* of the AFW organizational structure and provide continuous, complete environmental situational awareness. They are responsible for producing and disseminating mission-planning and -execution weather analyses, forecasts, and briefings for Air Force, Army, National Guard, and Reserve forces operating anywhere around the world.

- The 15th Operational Weather Squadron's area of responsibility includes 120 installations/sites in a 22-state region of the northeastern United States.

- The 17th Operational Weather Squadron's area of responsibility covers over 95-million square miles of the Pacific region including Australia, Korea and Japan.
- The 21st Operational Weather Squadron's area of responsibility includes Europe, Greenland, and most of Africa.
- The 25th Operational Weather Squadron's area of responsibility includes 68 installations/sites in an 11-state region of the western United States.
- The 26th Operational Weather Squadron's area of responsibility includes 70 installations/sites in a seven-state region of the south central United States.
- The 28th Operational Weather Squadron's area of responsibility includes sites throughout Central Command including southwest Asia and the Horn of Africa.



Air Force Operational Weather Squadrons (OWS) areas of responsibility (AORs) overlaid on geographic combatant commander AORs.

Weather Flights

Deployed in the field and focused on operational weather, USAF **Weather Flights** constitute the *third tier* of AFW and act as the prime interface with a USAF installation's flying and ground

operations. Weather Flights are located at military installations around the world and are the "eyes forward" for the OWS whose area of responsibility includes that installation.

Special Operations Weather

USAF special operations units provide limited forward weather observations in denied areas and transmit to a Joint Special Operations task force or next-echelon weather element on an as-required basis. Their tailored weather information and knowledge enable planning, command decisions, and execution of SOF operations. USAF combat weather technicians assigned to SOF units are expected to know and keep current on the entire environment in the isolated locations to which their unit deploys.

USAF- Army Weather Organizations

Weather airmen aligned with Army units directly support the Army G-2 intelligence centers and Amy fire support operations. Army weather organizations predict the impact weather will have on Army and joint operations, giving leadership at all levels the ability to adjust operational and tactical strategies helping to further mission success. (See section below on USA Weather Support Structure.)

Combat weather technicians and meteorologists assigned to support Army units are expected to forecast the weather anywhere their Army unit deploys. Army-trained weather personnel can parachute behind enemy lines and travel with a small platoon of soldiers, providing on-the-scene weather information for a variety of missions.

Combat Climatology

The 14th Weather Squadron is stationed in Ashville, North Carolina, where it is co-located with the National Climate Data Center, one of the environmental data centers under NOAA's National Environmental Satellite, Data, and Information Service (NESDIS). Its traditional mission has focused on combat climatology products and services to support Air Force operations worldwide. For more information on the 14th Weather Squadron and the National Climate Data Center, see the Climate Services section of this *Federal Plan*.

Space Weather Operations

AFW space weather forecasters provide space weather analyses, forecasts, and alert notification for all DOD agencies and U.S. Government systems. With observatories in Australia, Italy, Massachusetts, New Mexico, and Hawaii, USAF space weather technicians maintain a continuous observational watch on the Sun, which can emit electromagnetic energy and electrically charged particles capable of causing disturbances in the near-Earth environment and disrupting satellite operations and satellite-based communications. The mission of the AFW solar observatories is to monitor solar flares, noise storms and other releases of energy from the Sun and, when necessary, notify military and civilian concerned with space weather, power, and communications in countries throughout the world. For further discussion of the complementary roles of AFW space weather operations and the National Weather Service's (NWS) Space Weather Prediction Center, see the section on Space Weather Services.

AFW Reserve Component

The Reserve Component of AFW includes airmen in both the Air Force Reserve Command (AFRC) and the Air National Guard (ANG). AFW continues to integrate these forces to more closely align with active duty weather force operations. AFRC weather personnel augment the active duty force at all three tiers. In some cases, the AFRC provides very unique weather-related services not duplicated in the active duty force, such as AFRC's 53rd Weather Reconnaissance Squadron (see "AFRC Hurricane Hunters," below) and the ANG's Weather Readiness Training Center.

To augment OWS operations, AFRC organized two operational weather flights, each staffed by AFRC weather personnel, that are capable of augmenting an Operational Weather Squadron either in the continental United States or overseas. Additional AFRC weather personnel serve as individual mobilization augmentees assigned to various active AFW organizations at all echelons, typically in staff, forecasting, or scientific roles. There are also Reserve Component weather personnel in Air Reserve Technician positions, i.e., combined full-time civil service/Air Force Reserve military positions, employed by the 53 Weather Reconnaissance Squadron as airborne weather reconnaissance officers. Lastly, AFRC contract weather personnel provide weather services at AFRC-operated bases in the continental United States.

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 USA National Guard units. Air Combat Command-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 remotely piloted vehicle units (e.g., Predator). The ANG also has seven contract and four civil service locations, which are responsible for providing peacetime weather support to airfield operations.

USAF Products and Services

Space Launch Support

USAF meteorological support for space launches is discussed under the major section on Other Specialized Services.

Air and Space Natural Environment Modeling and Simulation

The Air Force Director of Weather carries out the responsibilities of the DOD Air and Space Natural Environment Modeling and Simulation Executive Agent (ASNE MSEA) in accordance with a Memorandum from the Under Secretary of Defense for Acquisition, Technology, and Logistics to the Secretary of the Air Force. These responsibilities include managing, coordinating, and implementing all aspects of modeling and simulation relating to the air and space natural environment related to planning, programming, monitoring, and reporting across all DOD components. The DOD ASNE MSEA ensures that DOD communities that 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.

AFRC Hurricane Hunters

53 WRS "Hurricane Hunter" WC-130J aircraft on-board radar (53 WRS website).

The AFRC 53rd Weather Reconnaissance Squadron, also known as the "Hurricane Hunters," provides an airborne means of collecting vital meteorological data, especially in and around tropical cyclones. The squadron's 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 NWS National Hurricane Center with highly accurate center fix locations as well as other meteorological parameters, including sea level pressure. In addition to tropical cyclone reconnaissance, the squadron collects meteorological information to improve wintertime West Coast forecasts and to support scientific field programs when possible.

DOD and National Aviation Support

OWSs provide flight weather briefings to aircrews operating within their area of responsibility without home station support or as requested by base- or post-level weather forces. The 15th Operational Weather Squadron, located at Scott AFB, Illinois, provides short-term backup services for the NWS Storm Prediction Center and Aviation Weather Center. In the event of an extended or catastrophic outage at either NWS center, essential staff would relocate to the AFWA facility at Offutt AFB, Nebraksa, where system and communications infrastructure exists to support relocation backup of these critical national missions.

At USAF bases and USA posts, AFW forces focus on their warfighter's mission requirements. These units provide and disseminate observations and develop tailored mission execution forecasts based on centrally produced guidance. For USAF operations, these weather professionals are normally assigned to a flight under an OWS in an USAF flying wing; however, individuals from the weather flight are integrated into flying squadron mission planning and execution processes. For USA operations, the Battlefield Weather Airmen professionals are normally assigned to combat weather teams at all levels of USA support. The weather airmen are integrated into all aspects of USA operations. In this capacity, weather forces supporting USAF and USA aviation operations infuse critical weather information at key points in the decision cycle to help aircrews maximize wartime capabilities, enhance flight safety, and optimize training effectiveness.

In FY 2011 AFW will continue to upgrade weather systems and processes that support all DOD aviation. The continued fielding of the Joint Environmental Toolkit and upgraded surface

weather sensors will produce more accurate and timely weather observation and forecast products.

Volcanic Ash Surveillance and Analysis.

One of the roles of the 2nd Weather Group at AFWA is to provide volcanic ash surveillance and analysis for DOD aviation operations worldwide. Analysts continuously monitor all active volcanoes, generating more than 4,000 bulletins per year. Tailored satellite imagery, graphical ash plume forecast, and text bulletins provide vital information needed to mitigate airborne volcanic ash as a threat to flight safety. The 2nd Weather Group also provides critical backup for NOAA's Washington Volcanic Ash Advisory Center.

Weather Specialty Teams

AFW weather experts are assigned to weather specialty teams in air and space operations centers. This crosscutting team integrates environmental information at key decision points of air and space operations planning, execution, and assessment. Armed with this information, decisionmakers can balance operational risks against mission need to optimize timing, tactics, target and weapons selection, and other factors affecting air and space operations.

NextGen Development

AFW continues active collaboration with the Next Generation Air Transportation System (NextGen) program, which is described more fully in the Aviation Weather Services section of this *Federal Plan*. Experiences gained through implementation of DOD's Joint METOC Data Base and machine-to-machine data services used by the USAF's primary automated mission planning systems are providing valuable lessons learned for NextGen's development.

U.S. Army

USA Weather Support Structure

The weather support structure within the Army is a mix of USA and USAF personnel and equipment in accordance with a USA-USAF agreement: (Army Regulation [AR] 115-10/Air Force Instruction [AFI] 15-157 (IP), Weather Support for the USA, 6 January 2010). This joint regulation describes the responsibilities of USAF support components and the Army Commands and Army Service Component Commands (ASCC) for providing weather support. Under AR 115-10/AFI 15-157, the USAF provides the Army with the necessary labor and unique tactical and fixed weather equipment to meet Army tactical, installation and airfield support requirements for both active and reserve components. Weather labor requirements for USA support are sourced from USAF active and reserve component weather personnel. The USAF assigns AFW personnel to provide direct weather support to the warfighting Army Commands and ASCCs at the following levels: Army Service Component Commands, corps, divisions, combat aviation brigades, brigade combat teams, armored cavalry regiments, Special Forces groups, Ranger regiments, and Special Operations aviation regiments. USAF OWSs and post-level weather organizations provide installation and tactical weather warning, observing, forecasting, special support, and staff weather officer (SWO) services to combat, combat support, and combat service support units throughout the peacetime/war continuum. Peacetime

installation and garrison activities include supporting flying operations at Army airfields and severe weather watch, warning, and advisory services for aircraft and installation resource protection. Per the USA-USAF agreement, the USAF is responsible for installation, operation, and maintenance of standard USAF meteorological and observing equipment at Army airfields. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army provides other tactical equipment to USAF personnel through an Army Table of Organizations and Equipment (TOE).

U.S. Army Forces Command, U.S. Army Europe, U.S. Army Pacific, U.S. Army Special Operations Command, Eighth U.S. Army, and U.S. Army Training and Doctrine Command (TRADOC) have AFW personnel providing daily installation and tactical weather support. The Army provides operational eeather support to Army research development, test, and evaluation (RDT&E) ranges, centers, and other research facilities using the Developmental Test Command's Meteorological Teams and USA Space and Missile Defense Command (SMDC) contractors. Developmental Test Command operational support is established under USA 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.

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

Headquarters, TRADOC, is responsible for leading the USA in development of USA-USAF interservice weather operations, services concepts, and doctrine required to conduct Army operations. TRADOC develops and manages USA weather training programs, documents standard USA equipment for use by AFW personnel in the TOE, and recommends modifications to the TOE and Common Table of Allowances to DCS, G-3/5/7 for validation. TRADOC processes tactical Army weather support requirements, represents the Army's warfighting functions by determining needed weather capabilities and processing weather requirements found in Joint and USA conceptual documents and originating from TRADOC centers and schools. TRADOC collects and processes weather requirements from TRADOC schools/centers, USA Medical Command, and USA Corps of Engineers (USACE). It collaborates with Headquarters, Department of the Army, and Headquarters, USAF, to recommend solutions to satisfy those requirements by processing tactical USA weather support requirements through the Joint Capabilities Integration and Development System (JCIDS) process.

Key mission areas for the next few years will be to assist the USAF with development and implementation of a new weather support concept to meet the needs of the USA's modular force, including brigade combat teams; to update weather support doctrine, policy, organization, and concepts; update tactics, techniques, and procedures; ensure weather effects to USA operations are documented and communicated to soldiers and AFW support personnel; and ensure USA weather support processes and procedures are trained across the TRADOC schools and centers. These mission areas are accomplished in coordination with the USAF SWOs and USA and USAF civilians assigned within TRADOC.

U.S. Army Intelligence Center of Excellence

The U.S. Army Intelligence Center of Excellence (USAICoE) is the functional proponent for USA tactical weather support. It represents the USA warfighter by processing weather support requirements and developing solutions to satisfy those requirements when they are the responsibility of the USA. In FY 2009, USAICoE hired a Department of the Army Civilian (DAC) to head the newly created USA Weather Proponent Office. This DAC heads USAICoE weather proponent efforts in JCIDS and Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities (DOTMLPF) work. This JCIDS and DOTMLPF work occurs within USAICoE and in conjunction with other USA Centers of Excellence and Army research and experimentation organizations. In FY 2010, the DAC led an Army-wide Weather Capabilities-based Assessment to determine capability requirements, gaps, and possible solutions. In addition to the DAC, the USAF has also assigned two active duty AFW personnel and a Department of the Air Force Civilian (DAFC) to USAICoE. The DAFC is responsible for assisting the 304th Military Intelligence (MI) battalion in conducting the Battlefield Weather Course (BWC). AFW personnel assist in overseeing the BWC, assist with the JCIDS and DOTMLPF work, and are the primary AFW interfaces with USAICoE Force Design, which develops TOEs for MI organizations. These TOEs document the equipment the USA is required to provide AFW personnel per AR 115-10/AFI 15-157 (IP). Most AFW teams are supported through a MI organization. The TRADOC Capability Manager for Sensor Processing employs one DAC to serve as the interface between the proponent (USAICoE) and the material developer to ensure as many requirements as possible are met by a developed solution. Currently, most of this work is directed toward the Program Manager for the Distributed Common Ground System-Army (PM DCGS-A); see discussion under “Products and Services” of IMETS.

USAF SWO at the USA’s Combined Arms Center

The USAF SWO at the USA’s Combined Arms Center (CAC), located at Fort Leavenworth, Kansas, provides oversight for the TOE and Modified TOEs (MTOEs) for AFW teams supporting USA operations. This CAC SWO is the USAF’s weather point of contact for implementing MTOE structure changes for support to Modular Forces in the Transformed Army. The CAC SWO also arranges for or provides environmental data, concepts of operation, 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, in 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 USA weather support instruction at the Command and General Staff College, to provide climate expertise to all units assigned or attached to Fort Leavenworth, and to be the SWO to the U.S. Army Aviation Center of Excellence (USAACE) at Fort Rucker, Alabama.

USA Products and Services

U.S. Army Artillery (ARTYMET)

ARTYMET crews in the active and reserve component sections of the Army are currently equipped with the legacy Meteorological Measuring Set (MMS) AN/TMQ-41 or its replacement, the Meteorological Measuring Set-Profiler (MMS-P) AN/TMQ-52A or AN/TMQ-52B systems.

The MMS AN/TMQ-41 is a mobile, upper-air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). It provides upper-air data to the Field Artillery Tactical Data System for use in adjusting artillery fire, to AFW personnel, and to the Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations.

The MMS-P is a major improvement over the MMS. The system is housed in a Command Post Shelter and transported on an 1152A2 HMMWV. Two additional HMMWVs are used to transport the crew and other equipment necessary to employ the system. The design of the MMS-P supports the new generation of indirect fire artillery weapons by providing highly accurate meteorological data to adjust artillery fire and achieve first-round hits or fires for effect. The MMS-P, which takes surface and upper air observations, provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to AFW services for weather forecasting; and to the Chemical Officer for obscurant deployment and for Chemical, Biological, Radiological, Nuclear (CBRN) defense operations. Its suite of meteorological sensors and associated software/models provide Field Artillery units with current and/or forecasted weather conditions at the points where artillery munitions are expected to engage a target. Efforts are ongoing to ensure that these surface and upper air observations are also sent back to military weather centers where they can be ingested into numerical meteorological analysis and forecasting models. The system provides meteorological data on demand, and its latency is reduced to less than 30 minutes, compared with hours for the MMS AN/TMQ-41. The profiler system includes frequent and updated meteorological messages that enhance the meteorological validity of products within a larger battle space, compared with the MMS AN/TMQ-41. The MMS-P uses the MM5 mesoscale meteorological model to assimilate data from a variety of sources and provide the best meteorological messages to the user in a timely fashion. It receives data from ground-based sources, radiosondes, and satellite-based sources. The latter include boundary data from communications satellites and data from polar-orbiting meteorological satellites, received through an onboard satellite reception capability. These incoming data help to improve the accuracy of the MM5 model. Further post-processing of the data generates the requested 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 it.

Integrated Meteorological System (IMETS)

The key system that provides weather support to the USA is IMETS, which is fielded by the USA and operated by AFW personnel. PM DCGS-A has assumed the IMETS program and is integrating IMETS into DCGS-A software and hardware. PM DCGS-A is also integrating the USAF's Joint Environmental Toolkit software into DCGS-A.

Army Test and Evaluation Command (ATEC)

The Developmental Test Command (DTC), a subordinate command of United States Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to USA Research, Development, Test and Evaluation (RDT&E). Under responsibilities established in AR 11510/ AFI 15-157 (IP), the DTC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support USA and other DOD RDT&E activities at eight USA installations.

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 USA 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 chemical, biological, radiological, nuclear, and explosive (CBRNE) defense modeling community in the development of new CBRNE hazard assessment models. Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, CBRNE hazard assessment, and air quality.

U.S. Army Space and Missile Defense Command (SMDC) Support to the Ronald Reagan Ballistic Missile Defense Test Site

A subcommand of SMDC provides operational support to the Ronald Reagan Ballistic Missile Defense Test Site, including support for range activities (local and remote missile launches), missile weapons readiness testing, aviation and marine operations, and emergency operations. For further description of this support service, see “Other Specialized Services” in Section 2.

Meteorological Education and Training

The U.S. Army Field Artillery School, Fort Sill, Oklahoma, is the proponent for upper air meteorological support to the USA. The 13S and 13W Military Occupational Specialty (MOS) have been combined into the 13T MOS for FY 2011. The associated course is now the Field Artillery Survey/Meteorological Crewmember Course. Active-duty Army survey and meteorological sections will complete the transition to the new 13T MOS structure by FY 2011. All soldiers in advanced individual training through the Field Artillery Survey/Meteorology Course are now being trained for the MMS-P (described above).

U.S. Navy

Operational Organizations

Oceanographer of the Navy

The Oceanographer of the Navy (CNO OPNAV N2/N6F5) is the resource sponsor for all Office of the Chief of Naval Operations (OPNAV) meteorological and oceanographic (METOC) programs of record and represents the Naval Oceanography Program (NOP) on the staff of the Chief of Naval Operations. His staff works closely with the staff of Commander, Naval

Meteorology and Oceanography Command (CNMOC), the operational arm of the NOP, to ensure the proper resources are available to meet mission requirements. The Oceanographer of the Navy acts as a liaison between CNMOC and the Chief of Naval Operations, serves as Naval Deputy to NOAA the Administrator, and represents the NOP in interagency and international forums.

Task Force Climate Change. In May 2009, the Chief of Naval Operations appointed the Oceanographer of the Navy to head Task Force Climate Change (TFCC). TFCC addresses emerging Navy needs and develops comprehensive approaches regarding Arctic and global climate change to guide future Navy public, policy, and strategy discussions. TFCC recommends policy, strategy, and investments for the Navy regarding the Arctic and climate change that are consistent with existing national, joint, and naval guidance, including National Security Presidential Directive 66/Homeland Security Presidential Directive 25 (NSPD-66/HSPD-25), Joint Vision 2020, Sea Power 21, the Cooperative Strategy for 21st Century Seapower, and the 2010 Quadrennial Defense Review. Recent TFCC accomplishments include the signing of the Navy's Arctic Roadmap in November 2009 and Climate Change Roadmap in March 2010 by the Vice Chief of Naval Operations and the signing of the Navy's Strategic Objectives for the Arctic by the Chief of Naval Operations in March 2010. The Arctic and Climate Change Roadmaps provide holistic, chronological, science-based guidance for future Navy action from now through 2040.

Naval Meteorology and Oceanography Command (NAVMETOCCOM)

NAVMETOCCOM serves as the operational arm of the NOP. Headquartered at the Stennis Space Center in Mississippi, it is a third-echelon command reporting to United States Fleet Forces. NAVMETOCCOM claimancy is globally distributed, with assets located on larger ships (aircraft carriers, amphibious ships, and C2 ships), shore facilities at fleet concentration areas, and larger production centers in the United States.

NAVMETOCCOM is focused on providing critical environmental knowledge to the warfighting disciplines of anti-submarine warfare (ASW); naval special warfare; mine warfare; intelligence, surveillance, and reconnaissance (ISR); and Fleet Operations (Strike and Expeditionary), as well as to the support areas of maritime operations, aviation operations, navigation, precise time, and astrometry.

Aerographer's Mate 2nd Class Derron Gee, from East Hampton, N.Y., runs a satellite loop computer program used to predict weather patterns in the metrological shop aboard the aircraft carrier USS John C. Stennis (CVN 74). (U.S. Navy photo by Mass Communication Specialist 3rd Class Kenneth Abbate)

Major activities and additional subordinates within the command currently include the following:

- Naval Oceanography Operations Command, Stennis Space Center, Mississippi
- Naval Aviation Forecast Center, Norfolk, Virginia, and detachments
- Naval Maritime Forecast Center, Pearl Harbor, Hawaii (with an activity in Norfolk)
- Strike Group Oceanography Teams in Norfolk, Virginia, San Diego, California, and Fallon, Nevada, with subordinate mobile environmental teams (in FY 2011, these three teams will merge into Fleet Weather Center Norfolk and Fleet Weather Center San Diego, with subordinate units and detachments)
- Naval Special Warfare Oceanography Center in San Diego, California (with components and detachments in Stuttgart, Germany; Norfolk, Virginia; and Pearl Harbor, Hawaii)
- Naval Oceanography ASW Centers in Yokosuka, Japan, and Stennis Space Center (with subordinate detachments)
- Naval Oceanographic Office (NAVOCEANO), Stennis Space Center
- Fleet Survey Team, Stennis Space Center
- Naval Ice Center, Suitland, Maryland
- Fleet Numerical Meteorology and Oceanography Center, Monterey (FNMOC), California
- U.S. Naval Observatory (NAVOBSY), Washington, D.C.
- Naval Meteorology and Oceanography Professional Development Center, Gulfport, Mississippi

The major NAVMETOCCOM production centers, NAVOCEANO, FNMOC, and NAVOBSY, support the Commander, Naval Oceanographic Operations Command with enabling capability. The command's operational model is based on standardizing services for each NAVOCEANOPSCOM directorate, automating everything that can be automated, and coupling situational awareness and a small on-scene presence, supported by a significant 24/7 reachback production capability at the major production centers.

Naval Oceanography Operations Command (NAVOCEANOPSCOM)

The NAVOCEANOPSCOM, headed by the Commander, Naval Oceanographic Operations Command, is an echelon four command that serves as the principal operational organization reporting to CNMOC. It 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. NAVOCEANOPSCOM encompasses nine warfighting and enabling directorates: Aviation Operations, Maritime Operations, Fleet Operations, Precise Time and Astronomy, Navigation, ISR, Mine Warfare, Naval Special Warfare and ASW. Each directorate determines how that directorate's services are delivered globally. The Commander, Naval Oceanographic Operations Command, supports the combatant commanders, national missions, and U.S. interagency and international partners.

Fleet Numerical Meteorology and Oceanography Center

FNMOC, which is an echelon four activity reporting to CNMOC, is the NOP production center for meteorology. This center plays a significant role in the national capability for operational weather and ocean prediction through its operation of global and regional METOC models that extend from the top of the atmosphere to the bottom of the ocean. Through close collaboration with NAVOCEANO, FNMOC is also 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.

Naval Oceanographic Office

NAVOCEANO is the NOP's production center for oceanography. Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in meteorology is closely linked with oceanography, which is the focus of the NAVOCEANO. NAVOCEANO primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. It is responsible for administration of a fleet of seven ocean-class hydrographic survey vessels.

United States Naval Observatory

NAVOBSY is the production center for precise time and astrometry. It is one of the oldest scientific agencies in the country, established in 1830 as the Depot of Charts and Instruments. Today, NAVOBSY is the national authority on Precise Time and Astrometry and distributes earth orientation parameters and other astronomical data required for accurate navigation and fundamental astronomy. NAVOBSY serves as the official source of time for the DOD 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. NAVOBSY performs an essential scientific role for the United States, the Navy, and the DOD, as its mission includes determining the positions and motions of the Earth, Sun, Moon, planets, stars, and other celestial objects; providing astronomical data; determining precise time; measuring the Earth's rotation; and maintaining the Master Clock for the United States. NAVOBSY astronomers formulate theories and conduct relevant research necessary to improve these mission goals. These astronomical and timing data, essential for accurate navigation and the support of communication on Earth and in space, are vital to the Navy and DOD. They are also used extensively by other government agencies and the public at large.

Navy Products and Services

Naval Oceanography Program (NOP)

The NOP provides global meteorological and oceanographic observations and forecasts, maritime geospatial-environmental information and services, and ocean surveillance critical for safe and effective DOD operations—particularly those of the Navy and the Marine Corps. Its mission is to protect the fleet, shape the battlespace, and maximize warfighting capability. The NOP includes oceanography, bathymetry, hydrography, meteorology, acoustics, geophysics, astrometry, geospatial information, and precise time.

Aerographer's Mate Airman Jonathan Salgado launches a weather balloon from the fantail of the aircraft carrier USS Theodore Roosevelt (CVN 71) to gather atmospheric data. (U.S. Navy Photo by Mass Communication Specialist Seaman Andrew Skipworth)

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 provides the DOD's global numerical weather forecasting capability and partners with AFW in flight weather forecasting, Joint operations, information management, and acquisition programs. It also has strong relationships with all five NOAA directorates.

FNMOC Numerical Weather Prediction (NWP) systems

FNMOC has had a long and productive history of implementing, evaluating, operating, maintaining, and improving Numerical Weather Prediction (NWP) systems specifically to meet U.S. Navy operational requirements. These requirements include the need for an 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 these requirements, FNMOC acquires and processes over six million observations per day, creating one of the world's most comprehensive real-time databases of METOC observations for real-time fusion and assimilation into its models. In addition, FNMOC is the designated DOD center for global NWP.

FNMOC 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 with embedded protection from DOD-certified firewalls to prevent outside intrusions. This requirement is driven by the importance of weather and ocean conditions on modern military operations, the need to use 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 decisionmakers without fear of interruption or compromise as a result of cyber terrorists or cyber warfare.

In general, FNMOC 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. FNMOC employs four primary models—the Navy Operational Global Atmospheric Prediction System (NOGAPS), the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), the Geophysical Fluid Dynamics Navy (GFDN) model, and the Wave Watch 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 FNMOC models and applications in some fashion, and forms the basis for the FNMOC global Ensemble Forecast System (EFS).
- COAMPS is a high-resolution, non-hydrostatic regional model, multiply nested within NOGAPS. It has proven to be particularly valuable for forecasting weather and ocean conditions in highly complex coastal areas.
- GFDN is a moving-nest tropical cyclone model, nested within NOGAPS. It is used to forecast tropical cyclone 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 parameters. All of the models are configured, scheduled, and operated under the central control of FNMOC 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 Worldwide Web via the FNMOC Centralized Atmospheric Analysis and Prediction System.

FNMOC Products and Services

FNMOC's complex and robust operational prediction capability is designed to deliver, in conjunction with NAVOCEANO, continuous support (24 hours per day, 7 days a week, 365 days a year) organized along the warfare areas. For example, some FNMOC products consist of detailed forecasts of wind stresses and heat fluxes to drive very high resolution ocean models at NAVOCEANO, which provide ocean thermal structure and currents in support of anti-submarine and mine warfare operations. Other products are near-shore wind, sea, and surf forecasts that directly support fleet operations through ship-to-objective maneuver. In many cases, the outputs of the FNMOC models feed directly into applications models, tactical decision aids, and other products that provide direct support to various weather-sensitive activities associated with the warfighting directorates identified above. These include optimum path aircraft routing, optimum track ship routing, issuance of high-winds and high-seas warnings, hurricane/typhoon sortie decisions, covert ingress/egress of SOF, ballistic missile targeting, cruise missile launch and targeting, radar performance 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.

FNMOC also provides a wide-range of METOC 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 FNMOC Tropical Cyclone Web Page, and various experimental satellite products fielded for evaluation in conjunction with the Naval Research Laboratory (NRL). The latter include satellite imagery that enhances the visualization of airborne sand and dust. In support of the Global Ocean Data Assimilation Experiment (GODAE), FNMOC also hosts the USGODAE Monterey Data Server. This system serves as a one-stop shop for METOC data and model products required to support global ocean modeling R&D. It also functions as one of two Argo Global Data Assembly Centers, hosting the complete collection of quality-controlled Argo temperature/salinity profiling float data.

Many of FNMOC's products are distributed to users over the Worldwide Web via the PC-based MetCast system, and can be subsequently displayed and manipulated on the user's PC with the Joint METOC Viewer software. This includes all standard METOC fields, synoptic observations, and satellite imagery. For users who require only graphical display of model-predicted meteorological or oceanographic fields, FNMOC provides a Web-based capability called WxMap (Weather Map), which requires only a Web browser for access and allows the user to select and quickly display predicted METOC fields for any user-defined geographical area.

All of FNMOC's production capabilities are fielded on a collection of computer hardware and software designated as the Primary Oceanographic Prediction System (POPS). POPS is organized into two subsystems: the Analysis and Modeling Subsystem (AMS) and the Applications, Transactions, 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. FNMOC also hosts a DOD High Performance Computing Modernization Program Distributed Center, which is closely integrated with POPS.

In addition to its primary role of focused support to the warfighter, FNMOC plays a key role in the U.S. national program for weather prediction. In this regard, FNMOC's tropical cyclone track predictions, widely recognized as among the best in the world, have proven to be especially valuable, with the NWS National Hurricane Center relying heavily on them. FNMOC benefits greatly from collocation with its supporting R&D activity, the Marine Meteorology Division of the Naval Research Laboratory-Monterey (NRL/MRY). This world-class research organization focuses on weather-related support to warfighting. FNMOC and NRL/MRY share space, data, software, and computer systems. Together with the nearby Naval Postgraduate School, they 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 FNMOC, is the optimum arrangement for transitioning R&D quickly and cost-effectively into new and improved operational weather prediction capabilities.

NAVOCEANO Products and Services

NAVOCEANO is the Navy's center for operational oceanographic support and provides daily analyses and forecasts of the ocean state with a series of global, regional, and coastal ocean circulation and wave models. The core of the system is the dynamic Navy Coastal Ocean Model (NCOM), which predicts three-dimensional ocean properties out to 96 hours. The 1/8 degree (14 km/7.5 nm) resolution Global NCOM covers the world from pole to pole and is coupled with the Arctic Polar Ice Prediction System, which forecasts ice properties for the National Ice Center. Nested 1/36 degree (3 km/1.7 nm) regional NCOM domains of about 20 by 20 degrees in areal coverage provide high-resolution ocean forecasts for regions of Navy and National interest. Twelve regional NCOMs are on line now, with 24 planned by 2014. Global and regional NCOM products and data fields are shared with NAVOCEANO's NOAA partners.

Nested in the regional NCOMs, NAVOCEANO runs a series of coastal, estuarine, and river domains with resolutions as fine as 1/360 degree (300 m, 1000 ft) or less in the support of mine warfare and homeland security efforts. When appropriate, coastal NCOMs are supplemented by other models including HYDROMAP, DELFT3D, and PCTIDES. These models are forced by global and regional atmospheric field data provided from FNMOC's NOGAPS and COAMPS runs. The NCOMs are initiated through the assimilation of ocean data from satellites (sea surface temperature and altimetry) and various surface and subsurface observing systems including ship data, ARGO profiling floats, and gliders. Observations are also used to evaluate model products and estimate model skill. In the near future, the Global NCOM will be replaced by the 1/12-degree resolution Global HYbrid Coordinate Ocean Model, which was developed under the National Ocean Partnership Program by a consortium of government and academic scientists, led by NRL Stennis and including NOAA/NCEP.

NAVOCEANO is the Navy's primary processing facility for a number of polar-orbiting and stationary satellite collection systems from NOAA, National Aeronautics and Space Administration (NASA), and international providers. It is nationally recognized for satellite-derived sea-surface temperature and satellite altimeter-derived sea surface topography and wave height observations. These products are shared with NOAA partners and are critically important to successfully running both the NAVOCEANO ocean models and FNMOC's NOGAPS and COAMPS atmospheric models. NAVOCEANO houses a DOD Supercomputer Resource Center that provides the power to run the center's operational ocean models. This center provides a firm link between research and operations, facilitating the rapid transition of the latest ocean modeling capabilities.

Naval Aviation Support

Many environmental conditions severely affect flight operations and mission accomplishment. 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. Parameters of importance 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 assessing likely mission success and the safety of pilots and their aircraft. Meteorologists are assigned to aviation forecasting hubs in the United States and at 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 (TAFs) for Navy airfields.

Meteorology and Oceanograpy Education and Training

Navy officers trained as meteorologists and oceanographers are all university graduates in meteorology, oceanography 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, which is collocated with USAF and Marine weather training at Keesler Air Force Base, Mississippi. Ongoing professional development for both officer and enlisted personnel is offered through the Naval Meteorology and Oceanography Professional Development Center in Gulfport, Mississippi (with Pacific and Atlantic detachments). This development center offers directorate-specific training, as well as training on general oceanographic knowledge.

U.S. Marine Corps

U.S. Marine Corps METOC Service

The mission of the U.S. Marine Corps METOC Service is to provide meteorological, oceanographic, and space environmental information, products, and services in support of Marine Corps military operations and garrison activities. The Marine Corps METOC support infrastructure is designed to readily deploy and operate in austere expeditionary environments in support of Marine Air Ground Task Force (MAGTF) operations.

The Deputy Commandant for Aviation, Headquarters U.S. Marine Corps, is the responsible office for Marine Corps METOC requirements and support. The Marine Corps METOC organization 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 Corps air stations, facilities, air ground training centers, and base installations. These activities are manned and equipped to provide direct aviation METOC support to host and tenant units at seven major air stations in the continental United States; one in Hawaii, and two in Japan. However, the number of off-site WSR88D Principal User Processors will be incrementally reduced starting in FY 2011.

FMF METOC activities are organized, trained, and equipped to provide tailored support products and services to all combat elements of a MAGTF. METOC support focuses on projected consequences for expeditionary maneuver warfare operations, particularly operational maneuver from the sea. FMF METOC activities are fully interoperable with 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, they are capable of planning, coordinating, and leading Joint METOC operations. Marine METOC forces can rapidly transition from a pre-crisis state to full operational capability in a distant theater, providing on-scene support to MAGTF, Joint, combined, allied, and coalition operations and other military operations as may be directed. FMF

METOC assets are permanently assigned to Marine Expeditionary Force headquarters (MEF), intelligence battalions, Marine Wing Support Groups (MWSG), and Marine Wing Support Squadrons (MWSS). There are three MEFs strategically positioned for global response. I MEF, which is based in southern California, and III MEF, which is forward based in Okinawa, Mainland Japan, and Hawaii, report to the Commander, Marine Forces Pacific. II MEF, which is 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). The three intelligence battalions in the Marine Corps are co-located with respective MEF headquarters. They 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 provide expertise, products, and services that directly support the intelligence preparation of the battlespace (IPB) process by helping intelligence analysts to evaluate, integrate, and synchronize METOC effects for both enemy and friendly courses of action.

METOC Support Team (MST)

The MST is task-organized and -equipped to provide a limited level of METOC support to combat elements other than an ACE (e.g., a Command Element (CE), Ground Combat Element, or Combat Service Support Element) and is assigned in support of Marine Expeditionary Unit 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. MST elements can consist of two to five Marines, dependent on mission. When deployed, an MST will normally be assigned to the intelligence division/section (GS-2) of the supported combat element or Marine Expeditionary Unit. The MST deploys with rugged, ancillary environmental collection and data

A weather Marine with the 13th Marine Expeditionary Unit takes a meteorological observation in the field. (U.S. Marine Corps photo)

processing equipment. During operations, team members organically collect METOC products, data, and information from the nearest deployed MetMF(R), Navy METOC OA Division afloat, host nation, or other METOC support organizations and agencies to satisfy METOC information requirements.

Marine Corps Products and Services

METOC Support Capabilities—Meteorological Mobile Facility-Replacement (MetMF(R))

Deployment of a MetMF(R) is the highest level of METOC support to a MAGTF or to Aviation Combat Element (ACE)-specific operations. The MetMF(R) provides a METOC support capability similar to that found in garrison METOC facilities. It is normally employed as part of a 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, which significantly enhances METOC situational awareness and overall efforts to support 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 provides tactical meteorological support to a MAGTF. It is replacing the legacy MetMF(R) with current and emerging state-of-the-art technologies offering a smaller overall size and increased mobility. These improvements significantly enhance the meteorological capabilities of a MEF.

Naval Integrated Tactical Environmental System (NITES IV)

Each MWSS and MST is equipped with a NITES-IV suite to provide forward METOC support. The NITES IV is a modular system that is used to provide limited METOC support in a stand-alone mode. Its capabilities can be increased by adding SIPRNET/NIPRNET connectivity. The NITES-IV suite consists of three laptops. Each laptop is designed to perform a different function, but all three are loaded with the same software and can perform the tasks of the others. Because of this redundancy, the NITES IV is often not deployed as an entire suite. Mission requirements, network availability, and embarkation space dictate how best to employ the NITES IV.

Automated Weather Observing System (AWOS)

The AN/TMQ-53 AWOS is an autonomous, man-portable, cost-effective, and rapidly deployable environmental sensing capability that senses all the atmospheric parameters required to support tactical aviation operations and associated safety of flight concerns.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

National Unified Operational Prediction Capability (NUOPC) Research Partnering Initiative

The Navy, AFW, and NOAA/NWS are partners in the NUOPC project to enable a Tri-Agency joint global atmospheric ensemble forecast system. The NUOPC focus is on next-generation systems for global numerical weather prediction (NWP), allowing for possible later expansion into other areas of numerical prediction with full implementation by 2020. The NUOPC vision is a national NWP system with interoperable components built on common standards and a common framework (the Earth System Modeling Framework), with managed operational ensemble diversity and a national global NWP research agenda to accelerate science and technology infusion.

The primary deliverable of NUOPC is a multimodel global ensemble forecast system that has the potential to establish the United States as the premier computer-modeling group in the world. Improvements in predictive capability are expected to result in better severe weather warnings (hurricanes, tornadoes, snowstorms), better cost avoidance for weather sensitive industries (agriculture, transportation, utilities, defense), and better informed decision making for industry, defense, and the general public. NUOPC efforts are coordinated by a Tri-agency management organization. The Executive Steering Group (ESG) has approved NUOPC Phase II implementation, with a goal of achieving an initial operational capability for a joint multimodel ensemble by December 2010.

U.S. Air Force Supporting Research Programs and Projects

Technology Transition Initiatives

The overarching objective of the USAF meteorological and space environmental technology transition program is to give capability designers, operational weather personnel, and weather information users the technology and tools to gain and maintain the advantage over a potential adversary. AFW's capability needs in the atmospheric and space environment sciences are articulated in the Initial Capabilities Document for METOC Environment, 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. AFW also uses cooperative development and testing agreements with other governmental agencies and laboratories, as well as with for-profit companies. Both the Air Force Institute of Technology and the Naval Postgraduate School offer USAF and Navy graduate students in the atmospheric and space environmental sciences opportunities to research topics of immediate operational interest to U.S. military services.

Cloud Forecasting

In applied meteorological R&D, the USAF is improving cloud-forecasting techniques by doubling the resolution, using a new cloud interpretation/typing scheme, and blending numerical weather prediction with forecast cloud advection techniques. The USAF 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.

Weather Forecast Modeling for USAF and USA Operations

AFWA participates in the collaboration that developed the Weather Research Forecasting (WRF) modeling framework and is now implementing research and operational models based on WRF. AFWA implemented its first operational WRF application in 2006 and will continue sponsoring and funding WRF application development, test, and evaluation at the National Center for Atmospheric Research and at NOAA's Earth System Research Laboratory. The Land Information System 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 AFW forces to provide better forecasts for low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also supports assessment of off-the-road trafficability for ground forces.

The Air Force Research Laboratory (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. AFW will continue these long-proven successes in FY 2011, looking for future opportunities to exploit the resources of AFRL to help AFW.

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

Tactical Decision Aids

AFW collaborates in the development of several tactical decision aids, including the Target Acquisition Weapons Software (TAWS), the Infrared Target Scene Simulator (IRTSS), and the Tri-Service Integrated Weather Effects Decision Aid (T-IWEDA). TAWS provides a joint mission-planning tool for combining platform, weapon, target, background, and weather factors to depict three-dimensional target acquisition and lock-on range and recognition range versus time.

- TAWS can be used to predict 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.
- 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. It aids in

selecting platforms, systems, or sensors, based on system rules with critical values and a forecast of weather conditions. Results are displayed on a red/yellow/green weather effects matrix and overlaid on a background map.

TAWS, IRTSS, and T-IWEDA integrate environmental impacts into the mission execution forecasts for operations command and control and for mission planning systems throughout the military planning and execution cycle. AFRL, the Navy's Space and Naval Warfare Systems Command, NRL, and the U.S. Army Research Laboratory (ARL) are developing modular programs as part of the T-IWEDA initiative. The Tactical Decision Aids program continues adding weapons systems and targets to the inputs to these decision aids at the request of users from the Services.

U.S. Army Supporting Research Programs and Projects

Army Materiel Command (AMC)

AMC is responsible for the RDT&E of equipment to satisfy the USA's requirements for meteorological support. AMC provides meteorological and climatological support to RDTE projects involving electro-optical sensors and 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 soldiers. AMC has several major subordinate commands and elements carrying out weather R&D responsibilities, including the Research Development and Engineering Command (RDECOM), which has responsibility for the USA's Research Development and Engineering Centers (RDECs) and ARL.

Battlefield Environment Division, ARL Computational and Information Sciences Directorate

The Battlefield Environment (BE) Division of the Computational and Information Sciences Directorate in ARL develops environmental knowledge and technology for the warfighter through a robust R&D program aimed at characterizing and modeling the lower atmosphere and its effects on USA systems and personnel at very high spatial and temporal resolution. Current R&D includes basic research and experimental characterization of urban wind flow and atmospheric turbulence for its effects on systems, the investigation of battlefield aerosols and hazards relevant to soldier health, and development of remote sensing capabilities to gather critical data. Numerical modeling R&D includes assimilation of battlefield meteorological observations into diagnostic and prognostic numerical weather models that address fine scale terrain and urban domain effects. This work includes the fusion of forward area observations into short-term Weather Running Estimate-Nowcasts (WRE-N). The applications and products developed from these efforts are often in the form of weather decision aids that compute weather effects and impacts on systems, sensors, personnel and operations and include recommended course of action planning such as optimizing mission flight profiles that avoid weather hazards and enhance the probability of mission success.

The BE Division consists of three branches located at ARL Headquarters in Adelphi, Maryland and at White Sands Missile Range, New Mexico. The division also administers a congressionally funded research program at Colorado State University. It provides a liaison to the Defense Weather Satellite System (DWSS) program office to coordinate on USA satellite data and

information requirements. The division works closely with AFWA to provide new DOD-relevant weather products for evaluation and operational hosting on AFWA's web page and provide web-enabled technologies delivering meteorological products and databases to the warfighter. Such technologies as T-IWEDA, the Aviation Weather Routing Tool (AWRT), WRE-N, the urban 3D Wind Field Model (3DWF), and other related products are transitioned to weather services capabilities being developed by the Distributed Common Ground Station- Army (DCGS-A). The BE program addresses needs for both the current and future force as well as coordinating with other agencies such as the FAA and Department of Homeland Security (DHS).

Battlefield Environment Division, Atmospheric Modeling Applications Branch

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

Meteorological forecast model applications are focused on the WRE-N and on meso/micro-scale NWP development, improvements, and evaluation. The WRE-N is a combined analysis and nowcast model system that will enable DCGS-A to satisfy its 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 dynamically produce rapid and continuous local corrections to regional scale mission planning operational forecasts, retain consistency with theater-wide operational forecast guidance from USAF and joint DOD weather centers, and ensure effective assimilation and fusion of local battlefield weather observations into each WRE-N modeling cycle. Such fine-scale battlefield weather modeling work leverages ARL's DOD Supercomputing Resource Center's (DSRC) capabilities to facilitate examination of the applicability of new atmospheric prediction models for USA scales (horizontal coverage of hundreds of kilometers and grid spacing of one kilometer or less). DSRC resources also allow for the testing of new boundary layer closures and data assimilation methodologies for potential USA applications.

Warfighter Decision Aids developed in the Atmospheric Modeling Applications Branch utilize meteorological model gridded output, such as from the WRE-N, to give commanders a tactical advantage with validated and verified, web-enabled, TDAs and associated databases. These databases describe the impacts expected and the resulting performance degradation 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. The current focus on user-tailorable atmospheric impacts decision support tools has led to the development of an initial My Weather Impacts Decision Aid (MyWIDA), the follow-on technology to T-IWEDA. MyWIDA allows users at all echelons to retrieve gridded weather databases needed to produce localized weather impacts products with tailored weather thresholds across specialized domains, all without dependency on connection within or to legacy tactical weather systems.

Work to develop manned and unmanned aircraft system applications has focused on the Aviation Weather Routing Tool (AWRT) and the upgrade, Atmospheric Impacts Routing (AIR) application, as the primary end product. AIR addresses a major operational flying mission shortfall by providing accurate weather impacts information to aircraft mission commanders. The AIR can be viewed as a sophisticated TDA that will generate a highly intuitive, 4-D graphical Google-Earth "fly through" display of adverse weather effects on aircraft systems. Perhaps more significantly, the AIR employs a computationally efficient automated search algorithm to identify optimum routes for minimizing adverse weather impacts along the flight path.

Battlefield Environment Division, Atmospheric Dynamics Branch

The BE Division's Atmospheric Dynamics Branch addresses basic research, atmospheric measurements, numerical modeling, and application development focused on fine scale, high resolution dynamics of the boundary layer atmosphere that impact soldiers and systems. Projects and capabilities in this branch include application of the branch-developed 3D Wind Field (3DWF) model for wind flow in urban and complex terrain. The 3dWF model is central to current development work on a 24/7 airborne hazard monitoring capability called the Local-Rapid Evaluation of Atmospheric Conditions system. This system is designed to give garrison commanders, emergency operations center planners, and first responder's immediate information about current wind flow over the installation and airborne hazard mapping following an airborne-release event. This information is critical for emergency planning and decisions on evacuation, shelter in place, and first responder routing. Follow-on research to extend the diagnostic 3DWF model has begun with the Atmospheric Boundary Layer Environment (ABLE) prognostic model for meteorology in urban and complex domains. ABLE addresses temperature, aerosol, and moisture dynamics as well as winds.

Basic research in the Atmospheric Dynamics Branch includes the improvement of theoretical models for propagation through optical turbulence and new approaches to modeling the

Accurate wind forecasts are essential to deliver airdropped supplies to the precise location. (U.S. Army photo)

transition from isotropic to non-isotropic mechanical turbulence near the surface. Data from highly instrumented wind flow experiments around buildings and turbulence measurements using two-dimensional arrays of sensors are used to verify and improve the 3DWF and ABLE models. This research is also used to characterize and more realistically simulate the environment of micro air vehicles in urban atmospheres and the effects of urban environments on transport and dispersion of aerosols.

Applied research efforts in the Atmospheric Dynamics Branch address the need for better environmental awareness to protect personnel and robotic systems. BED is looking at various approaches including biomimetic and biologically inspired methods to sense and react to the local environment and avoid or warn of hazards to platforms and sensors. This includes examination of emerging technologies such as exploitation of atmospheric propagation limited sensors operating in the Terahertz band, the extension to wider band acoustics applications, propagation effects on emerging ground-based solid state high energy laser systems, and development of sensitive single-ended lightning location and warning technology.

Battlefield Environment Division, Atmospheric Sensing Branch

The BE Division's Atmospheric Sensing Branch develops 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 Light Detection and Ranging (LIDAR) systems, experimental and theoretical developments to better understand acoustic propagation in urban environments, and aerosol measurement programs.

Models and codes under development will provide valuable tools for the investigation of environmental effects on acoustic sensor performance. These tools will enable more detailed studies of the effects of urban structures, turbulence, vegetation, and ground surfaces on sound propagation and the resulting effects on acoustic sensors. The decision aid models created from these new propagation models will be used to determine the impact of the environment on acoustic sensor systems and the detectability of acoustic signals on various military platforms.

Remote sensing of the battlefield environment, either through active LIDAR, passive infrared imaging, or passive spectral radiometric systems, has substantial importance for ISR operations. Development work in the Atmospheric Sensing Branch on advanced remote sensing technologies include systems engineering of next-generation LIDAR sensors, investigations using airborne Doppler wind LIDAR to study severe weather and hurricane environments, and algorithm development to enhance ISR products from remotely-sensed data, as well as developing an operational methodology for field deployment of LIDAR systems.

Aerosol research in this branch focuses on the ubiquitous but relatively unknown fraction of organic carbon aerosols (OCA) and natural biological aerosols (BA) in the atmospheric boundary layer. This elusive aerosol fraction, which contains partially volatile organic and biological molecules, is the primary interferant to BW/CW aerosol agent detection. OCA and BA also affect atmospheric visibility, atmospheric radiative balance, and human health. Research to further develop and employ ultraviolet-laser induced fluorescence (UV-LIF) and two-dimensional angular optical scattering techniques will improve the understanding of OCA and BA in natural atmospheric aerosols.

ARL Army Research Office

The Army Research Office, located in Research Triangle Park, North Carolina, manages the USA's extramural basic research program in the atmospheric sciences. This program is concerned with understanding the dynamical and physical processes of the atmospheric boundary layer at scales of interest to the USA (millimeters to tens of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through peer-reviewed, individual investigator grants and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer over land, where the USA operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding, modeling, and quantifying of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales.

Special funding areas are also managed under this ARO research program. The Defense University Research and Instrumentation Program provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research 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 is managed for selected topics. Funding for these programs is expected to remain about constant in FY 2011. However few new programs will be initiated because of existing commitments. The primary research focus continues to be the analysis and understanding of the stable boundary layer, augmented by external funding as a special program.

U.S. Army Corps of Engineers R&D

The USACE is responsible for reviewing all emerging USA systems for environmental effects, as stated in AR 70-1, Army Acquisition Policy. Within the Corps' Engineer Research and Development Center, the Army Geospatial Center and the Cold Regions Research and Engineering Laboratory (CRREL) develop tactical decision aids (TDAs) to interpret the impact of weather on terrain and provide actionable information about terrain and atmospheric and weather effects on units, systems, platforms and soldiers to support Battle Command and ISR decision making. When operational, TDAs are transitioned to the Digital Topographic Support System (DTSS) and the Commercial Joint Mapping Tool Kit (CJMTK).

Under its military mission, CRREL provides support to USA weapon systems RDTE with all-season solutions for mitigating adverse environmental effects on USA 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 receives special emphasis, particularly with regard to dynamics in propagation caused by properties and processes of materials near the terrestrial surface. CRREL develops databases and models for predicting the state of the terrain, including surface temperature, and TDAs supporting mobility analysis and sensor performance. In partnership with

the Army Geospatial Center, products transition to various research and engineering programs, including advanced technology demonstrations and specific programs of record such as DTSS and CJMTK.

Enhancements to ATEC Four-Dimensional Weather System (4DWX)

The Army RDT&E Meteorology Program is continuing to collaborate with the National Center for Atmospheric Research (NCAR) on enhancements to the ATEC 4DWX System, which is the backbone of the meteorological support infrastructure at the USA test ranges. ATEC 4DWX modeling capabilities include WRF-based real-time four-dimensional data assimilation at seven USA test ranges, and Global Meteorology on Demand, a globally relocatable mesoscale modeling system to support USA RDT&E (including DTC distributed and virtual testing) at locations other than the USA 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.

Major 4DWX system components include a central data archival/retrieval system for all range and external meteorological and model data, the WRF high-resolution mesoscale meteorological model, an innovative real-time data assimilation system, and a variety of user-configurable displays. The DOD High Performance Computing Modernization Office provided the 4DWX program with a high performance computer, which enables operational mesoscale ensemble forecasts to support major DTC test operations. The ensemble system uses both the Mesoscale Model Version 5 (MM5) and the WRF model as members of the ensemble set, which typically comprises 30 members having varying physics packages, boundary or initial conditions, and model type. System enhancements during FY 2010 included improvements to the WRF model's capability for deterministic numerical weather prediction specific to each test range, initial work on a hybrid data assimilation system to accept new types of data, and continued development of ensemble and probabilistic techniques. Work began on installing the AutoNowcaster thunderstorm prediction system at Redstone Test Center. Finally, the DOD High Performance Computing Modernization Office also provided funds and computer processing to develop a 4DWX-based climatology for Dugway Proving Ground.

System enhancements during FY 2011 will include continued WRF and data assimilation development focused on forecasting improvements at each range, in addition to advances that apply generally to all WRF applications, including continued work on the hybrid data assimilation approach. In addition, the AutoNowcaster installation at Redstone Test Center will be completed, and the Army will evaluate additional implementations at additional ranges where the radar data necessary for AutoNowcaster operations are available.

Atmospheric Sciences and Meteorological Support to the High Energy Laser Systems Test Facility (HELSTF)

HELSTF, which is a USA SMDC directorate located on White Sands Missile Range, is an element of the DOD Major Range and Test Facility Base with the mission of high-energy laser

(HEL) test and evaluation for future USA and sister-Service HEL weapons. In addition to HEL systems test and evaluation, on-site laser systems have been used extensively 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 through the atmosphere. Many unique meteorological instruments are maintained to support this critical data collection for HEL testing. The HELSTF meteorological team also supports critical safety analysis of atmospheric dispersion for the very toxic fuels used to power some HEL systems.

U.S. Navy Supporting Research Programs and Projects

Program Alignment. The NOP is changing focus from an acquisition-based program to "in stride" technology transition that will rapidly transition R&D into operations and influences the Navy's science and technology investments. Emerging R&D technologies will be tested in computational and operational environments and transitioned after an appropriate collaborative period.

SPACE WEATHER SERVICES

For purposes of this *Federal Plan*, Space Weather Services are those specialized meteorological services and facilities established to meet the needs of users for information on extreme space weather events, also known as solar storms, which can affect terrestrial systems, the Earth's atmosphere, and the near-Earth space environment. Space weather services include monitoring and reporting of solar storms and their effects on the Earth's atmosphere and geomagnetic fields. Early warning of an approaching solar storm, so that timely protective response is possible, is an important part of space weather services.

OPERATIONAL PROGRAMS INCLUDING PRODUCTS AND SERVICES

Space Weather Prediction Center

The National Centers for Environmental Prediction's (NCEP) Space Weather Prediction Center (SWPC), within the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), is the Nation's official source of space weather alerts, watches, and warnings for 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 provides real-time monitoring and forecasting of solar and geophysical events, conducts research in solar-terrestrial physics, and develops techniques for forecasting solar and geophysical disturbances. These observations and predictions are an effort to promote public safety and mitigate economic loss that could result from disruption of satellite operations, communications, and navigation systems, and electric power distribution grids. The SWPC, with the U.S. Air Force, jointly operates the national civilian Space Weather Operations Center. Forecasts, alerts, and warnings are provided to customers on a 24 hour-per-day, seven day a week basis. SWPC products are synthesized from over 1,400 data streams providing observations of the solar terrestrial environment, including x-ray flux, charged particles, and magnetic field changes on the sun, in interplanetary space, and at Earth. SWPC also explores and evaluates new models and products and transitions them into operations. The SWPC takes a leading role in advocating and specifying new space-environment sensors for operational use.

The SWPC provides services to a broad user community of government agencies, industries, public institutions, and private individuals involved in satellite operation, space exploration, radio navigation, high-altitude polar flights, high-frequency communications, remote intelligence gathering, long-line power and data transmissions, and geophysical exploration. Also, SWPC serves as the primary 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.

AIR FORCE WEATHER (AFW)/AIR FORCE WEATHER AGENCY (AFWA)

AFWA's Space Weather Flight is the Department of Defense's (DOD) reach-back center for space environmental services operations. These personnel apply a detailed understanding of the space environment to translate raw data into useful military intelligence information, which can be integrated into the Common Operating Picture.

Forecasters in the Space Weather Flight, 2nd Weather Squadron (2 WS), 2nd Weather Group (2 WXG) at AFWA, monitor the Sun's emissions and provide mission-tailored analyses, forecasts, and warnings. Their products are used for mission planning and environmental situational awareness by National agencies, DOD operators, warfighters, and decision makers. Solar emission of highly energetic particles, X-rays, and radio bursts can produce the following effects on DOD operations:

- Electrical anomalies and degrading of components to satellites and other equipment in orbit above the protective levels of the atmosphere.
- Impact on electromagnetic signals, influencing high frequency (HF) communications, ultra high frequency (UHF) communications, and Global Positioning System (GPS) satellite navigation signals.
- Increased drag on satellites in low-earth orbit.
- Increased interference or false returns to sunward/poleward-looking radars.
- Potential health impact of radiation exposure to high-altitude aviators and those flying over polar regions.

The Space Weather Flight also provides both immediate and extended backup support for the SWPC. The backup may include the use of on-site personnel or augmentation personnel from SWPC, depending on the severity and expected duration of the SWPC outage.

The 2 WS space weather technicians located at Offutt AFB, NE, and at solar observatories around the globe never let the sun slip from view. They provide timely, relevant, and accurate space weather information to DOD personnel, issuing approximately 15,000 forecaster-in-the-loop and automated textual and graphical products warning of significant solar activity daily. 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. Air Force Weather (AFW) has outlined plans to modernize ground-based space sensing and is collaborating with U.S. and allied government and civilian agencies to achieve a robust space-sensing capability.

AFWA's 2 WS operates the Solar Electro-optical Observing Network (SEON), a network of five ground-based observing sites located around the globe providing 24-hour coverage of solar phenomena at optical and/or radio wavelengths. The network sites are: Detachment 1,

Learmonth, Australia; Detachment 2, Sagamore Hill, MA; Detachment 4, Holloman AFB, NM (relocating to Kirtland AFB, NM); Detachment 5, Palehua, HI (relocating to Kaena Point, HI); and a contract site in San Vito, Italy.

Solar optical and radio telescopes at Learmonth, Australia. (US Air Force Released)

The SEON network sites utilize the Radio Solar Telescope Network (RSTN) and/or the Solar Observing Optical Network (SOON). The RSTN is composed of the Radio Interference Measuring Set and the Solar Radio Spectrograph and is used to monitor solar radio bursts at eight specific frequencies as well as a spectral band. The SOON is used to monitor solar flare activity, which can trigger coronal mass ejections that may interact with the Earth's magnetic field to create geomagnetic storms. SOON images the Sun in the hydrogen-alpha wavelength, which reveals the complex solar activity in the lower atmosphere or chromosphere, as well as imaging the Sun in the continuum (pseudo-white light), which shows sunspots on the Sun's surface or photosphere. SOON also creates magnetograms by analyzing right-hand and left-hand circularly polarized light to image the line-of-sight component (Doppler shifting) of the magnetic field in the photosphere. When solar emissions are observed over threshold levels, solar analysts transmit activity messages that are used to prepare mission-tailored analyses, forecasts, and warnings used for mission planning and environmental situational awareness.

AFWA employs a worldwide network of ground-based ionosondes and other sensors to provide environmental data in the ionosphere. They manage seven automated Digital Ionospheric Sounding Systems (DISS) to measure electron density profiles in the ionosphere. The DISS network is undergoing modernization as part of the next-generation ionosonde (NEXION) fielding that started in summer of 2009, which will culminate in 30 NEXION sites worldwide.

AFWA funds a database of 27 international ionosonde sites at the National Geophysical Data Center in Boulder, CO.

National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory operates a complementary global network of over 125 sensors, deriving ionospheric line-of-sight total electron content from GPS signals and provides these data to AFWA. The Air Force Research Laboratory (AFRL) at Hanscom AFB, MA, provides ionospheric scintillation data from a global network of 22 UHF and L-Band receivers, supporting Air Force command and control satellite systems and strategic long-range radar systems. From space, two primary operational Defense Meteorological Satellite Program (DMSP) satellites providing space environmental data are in polar orbits at about 450 nautical miles (nominal) at all times. The DMSP Special Sensor-Auroral Particle Sensor measures low energy precipitating electrons that interact with the auroral boundary causing the aurora and other high-latitude phenomena. The DMSP Special Sensors-Ions, Electrons, and Scintillation sensor provides topside measurements of the ionospheric environment, complementing ground-based sensors. These data are utilized to assess the impact of ionospheric conditions on ballistic-missile early warning radar systems and long-range communications. Additionally, the data are used to monitor global auroral activity and to predict the effects of the space environment on satellite operations. The Solar X-Ray Imager aboard NOAA's geosynchronous GOES-14 satellite monitors solar X-ray emissions and provides near real-time display at AFWA and the Space Weather Prediction Center (SWPC) in Boulder, CO. AFW also leverages space-based data from NASA and other agencies.

AFW will continue to lead the DOD in space weather operations in FY 2011 and beyond. In FY 2011, AFW will maintain its aggressive posture to upgrade its solar equipment and processes, along with providing new or upgraded facilities for some solar locations.

United States Geological Survey (USGS)

The Geomagnetism Program (http://geomag.usgs.gov) of the USGS Geologic Hazards Science Center 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, CO, where they are processed and analyzed. Data are then transmitted to the SWPC and AFWA.

USGS observatories are operated in cooperation with Intermagnet (www.intermagnet.org), an international consortium overseeing the operation of over 100 geomagnetic observatories distributed around the globe. The USGS Geomagnetism Program is an integral part of the National Space Weather Program.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

SWPC Research Projects

The SWPC conducts research in solar-terrestrial physics and develops techniques for forecasting solar and geophysical disturbances.

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.

National Aeronautics and Space Administration (NASA)

Science Mission Directorate/ Heliophysics Division

The Heliophysics Division of the NASA's Science Mission Directorate (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 14 missions involving 27 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, as part of the *Living with a Star Program*, NASA launched the Solar Dynamics Observatory (SDO) on February 11, 2010, and is developing the Radiation Belt Storm Probes (RBSP) mission for launch in 2012.

Currently, four 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 the 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 led to the inclusion of this type of mode into the RBSP project. SDO, the newest member of the fleet of Heliophysics spacecraft, has a separate, high-speed, data link that makes 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 (CCMC), an interagency collaborative activity involving the National Science Foundation (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. The intent of this effort is to transfer the tools and techniques of CCMC research into the operational arena—the ultimate objective of the National Space Weather Program (NSWP).

National Science Foundation (NSF)

The National Science Foundation (NSF) supports the NSWP in pursuing the program's objective 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 that 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 2010 was estimated at $14 million and is expected to be around the same level in FY 2011.

Air Force Research Laboratory (AFRL)

The Air Force Research Laboratory (AFRL) supports AFW's space weather mission by executing research conducted by external agencies and by conducting in-house research on space weather. 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, ionospheric characterization, solar-radio and optical-emissions observing, and the Operational Space Environment Network Display suite of web-based products.

SURFACE TRANSPORTATION SERVICES

For purposes of this *Federal Plan*, Surface Transportation Services are those specialized meteorological services and facilities established to meet the weather information needs of the following surface transportation sectors: roadways, long-haul railways, the marine transportation system, rural and urban transit, pipeline systems, and airport ground operations. The roadway sector includes State and Federal highways and all State and local roads and streets. The marine transportation system includes coastal and inland waterways, ports and harbors, and the intermodal terminals serving them. Rural and urban transit includes bus and van service on roadways and rail lines for metropolitan subway and surface "light-rail" systems. Operational and supporting research programs for Aviation Services are often also relevant to airport ground operations, but program budgets counted in Aviation Services are not double-counted here under airport ground operations, and vice versa.

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS)

NWS Marine and Coastal Weather Services is the lead for the Nation's marine and coastal weather services, encompassing a vast area from intercoastal waterways and near-shore bays and inlets to the open oceans spanning much of the northern and western hemispheres. The program is aimed at promoting safe and efficient transportation, in support of both commercial and recreational interests, and with consideration of the expanding and weather-sensitive U.S. coastal population. Forty-seven coastal WFOs and three components of the National Centers for Environmental Prediction (NCEP) provide forecasts, analyses, watches, warnings and advisories of maritime conditions as well as coastal and tropical hazards. These services are provided for coastal waters, offshore high seas waters, and Great Lakes nearshore and open lake waters. Coastal WFOs have responsibility for forecasts and warnings extending nearly 100 nautical miles from the shore. The centralized Ocean Prediction Center of NCEP has responsibility for offshore and high seas waters, meeting U.S. international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea, to which the United States is a signatory.

Using observational data sources such as buoy observations and satellite imagery, plus numerical prediction models, NWS forecasters monitor weather conditions continuously over marine zones. Routine forecast products and analyses, watches, warnings, and advisories are disseminated to describe maritime conditions and tropical-storm and coastal hazards. Marine and coastal products describe wind, waves, visibility, icing, coastal flooding, severe weather, high surf, and rip currents. Tropical-storm products describe hazards associated with tropical cyclones such as storm surge, wind, waves, and inland impacts.

The Marine and Coastal Services program collaborates widely within and outside of NOAA. The program 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. It 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 (USACE) to operate the Nation's Marine Transportation System safely. It works with the DOD, FEMA, and USACE to provide tropical cyclone services; with the USCG, Navy, Air Force, and private entities to disseminate weather to mariners; with 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, Department of Defense, and Department of Homeland Security for forecasting services in support of hazardous material spill response; marine area search, rescue, and recovery operations; and security needs.

National Ocean Service Marine Transportation System Services

NOS is the primary civil agency within the Federal government responsible for the health and safety of our nation's coastal and oceanic environment. It monitors, assesses, and forecasts conditions in the coastal and oceanic environment to maintain a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. Largely through the Center for Operational Oceanographic Products and Services (CO-OPS) program line, NOS acquires data on water levels and currents, as well as physical oceanographic and meteorological data, and distributes these data and circulation predictions to users as elements of an integrated NOS program. This program thus provides a comprehensive science-based suite of information required by the marine transportation community to ensure safe and efficient transportation, including the transport of hazardous materials. NOS also provides coastal oceanographic and meteorological products required by the NWS to meet its short-term weather and forecasting responsibilities, including tsunami and storm surge warnings. NOS manages several observing systems and programs; however, four in particular are heavily linked to the capability of NOAA to meet the marine transportation needs of the nation:

National Water Level Observation Network (NWLON). NOS manages the NWLON, which officially consists of 210 stations located along the coasts of the United States and the Great Lakes, from which water level data as well as other oceanographic and meteorological data are collected and disseminated. NWLON provides data and supporting information to a number of NOAA and other Federal programs, such as the NOAA Nautical Charting Program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate Services Program. By FY 2011, approximately 192 of the 210 NWLON stations will contain at least one meteorological sensor (an anemometer, a barometer, an air temperature sensor, and at some Great Lakes stations a relative humidity sensor), and 146 stations will be outfitted with a full suite, which includes dual anemometers, a barometer, and an air temperature sensor. Water level and meteorological data are automatically formatted into SHEF bulletin format for inclusion into the NOAA Advanced Weather Interactive Processing System. Beginning in FY 2011, NOS intends to outfit remaining single-anemometer stations in remote areas with a redundant sonic anemometer. This is a departure from the current practice of employing dual

propeller anemometers that contain moving parts. This new redundant sensor will allow for more certainty in quality control and will also be easier to maintain.

Physical Oceanographic Real-Time System (PORTS®). PORTS is a decision support tool that improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS measures and disseminates observations and predictions of water levels, currents, salinity, bridge air gap and many meteorological parameters, needed and requested by mariners to navigate safely. There are 20 existing PORTS systems that comprise a total of 78 PORTS water level stations. Currently, 61 of these stations contain at least one meteorological sensor (anemometer, barometer, air temperature sensor or a visibility sensor).

PORTS is a partnership program in which local operating partners fund the installation and operation of the measurement systems. The PORTS systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. The largest of NOS's existing PORTS installations contains over 100 separate instruments. The smallest consists of a single water level gauge and associated oceanographic and meteorological instruments. 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, e.g., EXXON *Valdez*, can cost billions of dollars and destroy sensitive marine habitats critical to supporting coastal marine ecosystems. PORTS provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur. An extensible PORTS can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS). In FY2010, NOS installed its first visibility sensor as part of the PORTS program in Mobile Bay, AL, which provides navigation guidance for port traffic, as well as forecast guidance for the local WFO. A desired outcome for FY 2011 is to begin the planning and installation of visibility sensors in additional PORTS systems, such as those in Narragansett Bay and Chesapeake Bay.

National Operational Coastal Modeling Program (NOCMP). NOCMP serves a variety of users with oceanographic nowcast and forecast products for ports, estuaries, and the Great Lakes. The integration of PORTS technology with numerical circulation models allows nowcasts and predictions of parameters within the boundaries of the models even for 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 Chesapeake 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 NOAA's Office of Oceanic and Atmospheric Research and NWS, the NOS CO-OPS program now runs five 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 materials in

the ecosystem essential for effective marine resource management and homeland security. Several new models are being developed for FY 2011 release.

The NOS Continuous Real-Time Monitoring System (CORMS). CORMS was designed to operate on a 24-hour-per-day, 7-days-per-week, basis to ensure the accuracy and working status of oceanographic and meteorological observations acquired via the NWLON and PORTS programs. CORMS improves the overall data quality assurance of real-time measurements, reduces NOAA's potential liability by not publicly 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 3, is now operational and provides personnel with alerts as soon as any sensor data are suspect or any communications problems arise. This enables speedier communication to instrument labs and field crews, who may either fix the station remotely or initiate emergency maintenance, thereby decreasing downtime of a particular station or sensor. FY 2011 plans for CORMS 3 include additional enhancements to generate internal reports on station statistics and tighter quality control threshold values used to flag questionable data.

United States Coast Guard (USCG)

Although no Coast Guard 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 NWS. Coast Guard communications stations broadcast NWS marine forecasts, weather warnings, and weather facsimile charts. They 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. The IIP uses sensor-equipped aircraft to patrol the Grand Banks of Newfoundland to locate and track icebergs that 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 the 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 Office of Marine Transportation Systems at Coast Guard Headquarters. Field management of Coast Guard meteorological support services is performed at the Coast Guard Area and District levels.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

Federal Highway Administration (FHWA)

The FHWA coordinates a number of activities aimed at improving safety, mobility, productivity, environmental quality, and national security on the nation's highways. These activities include identification of weather impacts on the roadway environment, traffic flow, and the operational decisions that are made because of adverse weather. The FHWA supports and conducts research to advance road weather management tools, as well as promoting the best weather management practices. The FHWA supports these activities through the Federal-Aid Highway program and by initiating national coordination research efforts. The FHWA has no direct operational systems since it operates neither the highway system nor the road weather observing systems that serve State and local highway operators, private road users, and the traveling public. FHWA research activities are conducted as partnerships with other public agencies, national laboratories, the private sector, and universities.

FHWA Road Weather Management Program

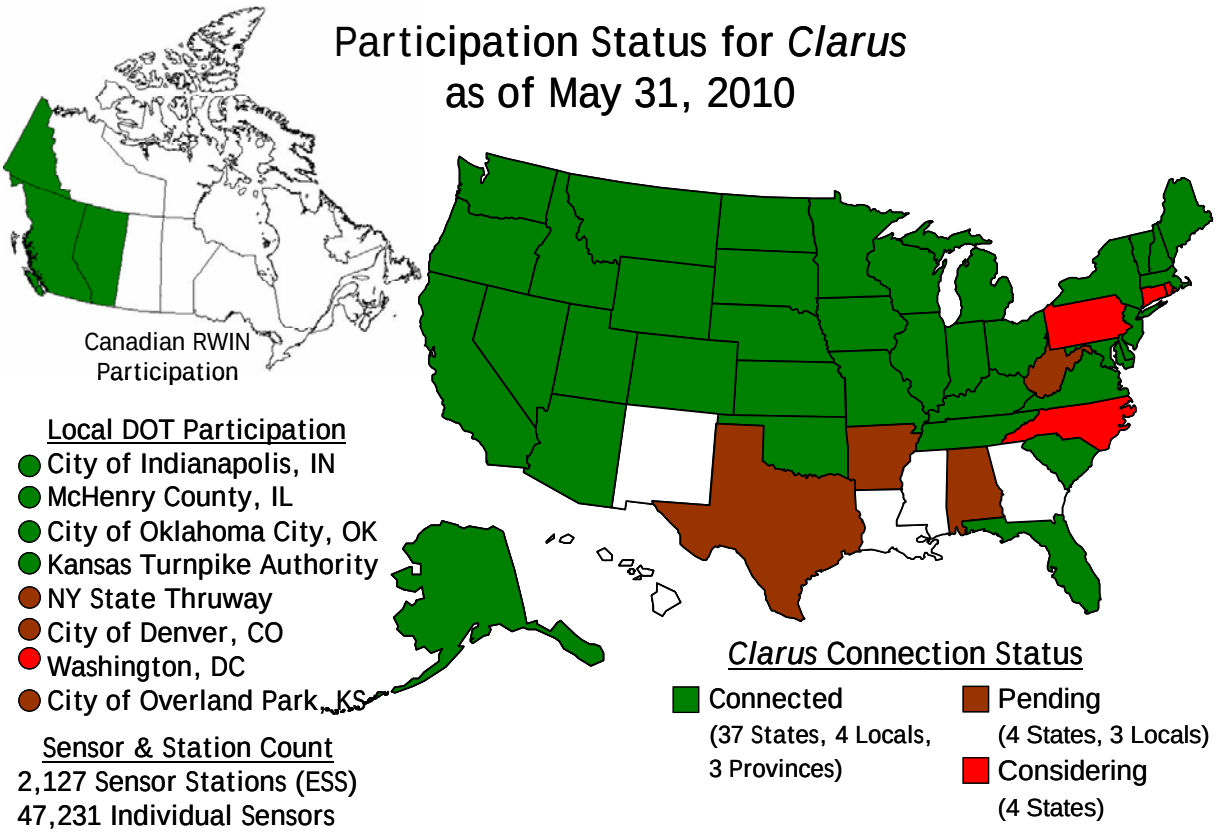
Coordination of the FHWA's weather-related research activities has been centered in the Road Weather Management Program (RWMP) within the Office of Transportation Operations since 1999. The goal of promoting road weather research and development was further defined in 2005 by the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Title V, Subtitle C—Intelligent Transportation System Research, Section 5308 of this law contains specific reference to a “Road Weather Research and Development Program.” The bill directs the Secretary of the U.S. Department of Transportation (DOT) to carry out research and development called for in the National Research Council's 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: (1) enable efficient technology transfer; (2) improve education and training of road weather information users, such as State and local transportation officials and private sector transportation contractors; and (3) coordinate with transportation weather research programs in other modes, such as aviation.

Funding authorized for Section 5308 was $5 million per year for fiscal years 2006 to 2009. Because SAFETEA-LU was extended through 2010, the same authorization applied during this

past fiscal year. The FHWA Road Weather Management team executes the program in coordination with the Intelligent Transportation Systems (ITS) Joint Program Office. The goals and objectives of the RWMP and its associated roadmap are aligned with the legislation. Several FY 2010 efforts and initiatives within the RWMP are satisfying the requirements in the bill, including the *Clarus* initiative, the IntelliDrive[SM] initiative, support for traffic managers, and weather information in the 511 National Traveler Information System.

Integrating Road Weather Observing Systems—The *Clarus* Initiative

Road weather observing-system stations are known as Environmental Sensor Stations (ESS). Nearly 2,500 ESS in the United States are owned by State transportation agencies. More than 2,100 of these are field components of Road Weather Information Systems. ESS are fixed and tend to include in situ sensors for the most common atmospheric weather variables, as well as pavement and subsurface temperature probes and sensors for pavement chemical concentration and/or pavement freezing point. A growing trend is the use of mobile environmental sensors, which are being deployed on vehicles to observe weather and pavement conditions as the vehicles travel the roadways.



Before 2006, ESS data from across the United States had never been collected, formatted, and quality-checked in a uniform manner at the national level. Nor had it then been made available to all users from a "one-stop shop" location so that it could be more effectively used by members of both the weather enterprise and the transportation community. A U.S. DOT-sponsored initiative entitled *Clarus* (http://www.clarusinitiative.org/) aims to correct this shortfall by 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 transportation agencies' 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 *Clarus* System data is provided through an open Internet data portal (http://www.clarus-system.com/).

The *Clarus* Concept of Operations and the *Clarus* System design have been completed. A proof-of-concept demonstration occurred in 2006, and regional demonstrations were initiated in 2007. In phase one of the *Clarus* Multistate Regional Demonstrations, three teams of State and Provincial DOTs identified their needs for new products, tools, and services in Concept of Operations documents. Phase two is a Connection Incentive Program that provides grants to public transportation agencies to assist them in connecting their ESS networks to the *Clarus* System. The third phase of the demonstrations, which began in Fall 2008, focuses on development, deployment, and evaluation of *Clarus*-enabled services, based on the needs documented in the phase one Concepts of Operations. In FY 2010, these services were designed and implemented, and evaluation plans were prepared. During FY 2011, data will continue to be collected and five *Clarus*-enabled services will be evaluated. These services include enhanced road weather forecasting, a seasonal weight restriction decision support tool, a non-winter maintenance and operations decision support tool, a multistate control strategy tool, and enhanced road weather content for traveler advisories.

The FHWA awarded research grants to graduate students in FY 2010 to develop additional road weather tools and applications that use *Clarus* System data. This research seeks to foster collaboration between transportation engineering, computer science, and atmospheric science disciplines and to support research that will improve surface transportation weather management and operations, create innovative interfaces, and/or develop new applications including weather-responsive traffic management tools.

The RWMP has worked closely with NOAA to ensure that the experimental *Clarus* System can be transitioned to the NWS. The FHWA and NOAA signed a memorandum of understanding (MOU) in July 2005 to establish a framework for cooperation and coordination, enabling the provision of timely, accurate, and relevant environmental data and services to address the nation's surface transportation weather needs. Although this MOU expired on July 20, 2010, work continues to translate the *Clarus* needs into the appropriate requirements and determine which requirements can be incorporated into NOAA's Meteorological Assimilation Data Ingest System. The two agencies will then collaborate to develop a work plan for execution.

FHWA Participation in Interagnecy Projects

To address some of the challenges related to surface weather observations, the FHWA is participating in several OFCM projects including the Weather Information for Surface Transportation (WIST) Working Group, the Committee on Integrated Observing Systems (CIOS), and the Multifunction Phased Array Radar (MPAR) Joint Action Group, among others. 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.

IntelliDrive℠ Initiative—Vehicle Weather Observations

In January 2009, the U.S. DOT renamed the Vehicle Infrastructure Integration initiative "IntelliDrive" (http://www.intellidriveusa.org/). IntelliDrive is a multimodal initiative that aims to enable safe, interoperable, networked wireless communications among vehicles, the infrastructure, and personal communications devices. IntelliDrive research is sponsored by the U.S. DOT and others to leverage the potentially transformative capabilities of wireless technology to make surface transportation safer, smarter, and greener. Once implemented, the system will 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.

Some of the weather-related data items that could be directly measured or inferred from vehicle sensor systems including precipitation detection, ambient air temperature, atmospheric pressure, visibility information, road surface temperature, and road friction coefficient. The use of vehicle sensor data to improve information products on weather and road conditions could revolutionize the provision of road weather information to transportation system decision-makers, including travelers. For example, vehicle-based probe data will significantly increase the density of weather observations near the surface and also provide unique datasets for deriving and inferring road-condition information.

The RWMP sponsored a feasibility study to explore and assess the utility of using data from vehicles to improve surface transportation weather observations and predictions. This work led to the development and prototyping of a Vehicle Data Translator (VDT) to process weather, pavement condition, and other data collected by vehicle-based systems associated with the IntelliDrive initiative. During the past two winters, data were collected on the IntelliDrive Development Test Environment in Detroit, Michigan. During FY 2011, the data will be used to refine the VDT and develop data quality checking algorithms. Data will also be used to address technical issues and challenges related to the use of vehicle data and to provide recommendations that will help ensure successful exploitation of vehicle probe data in weather applications. Researchers will also explore the variability of data collected by vehicle sensors from different manufacturers in the same geographic location during FY 2011.

In partnership with the National Center for Atmospheric Research (NCAR), the FHWA will begin an expanded IntelliDrive Mobile Data Collection and Application Demonstration project in FY 2011. This project will demonstrate how weather, road condition, and related vehicle data

may be collected, transmitted, processed, and used for decisionmaking. Using existing State DOT fleet infrastructures and wireless communications technologies, the project will help determine requirements, standards, and procedures for the collection and processing of weather, road condition, and vehicle status variables from mobile sources. The project will build upon the capabilities of the VDT to ingest data, check data quality, and aggregate data for use in applications. Mobile weather and road condition data will also be integrated into the *Clarus* System. Ultimately, decisionmakers will have the benefit of decision support tools that have access to data provided by millions of vehicles through the IntelliDrive initiative.

Support for Traffic Managers

In 2006, the RWMP developed a five-year roadmap for Weather-Responsive Traffic Management. The roadmap identifies the goals and activities that the 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 October 2006. This phase of 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 including gap acceptance, car following, and lane changing was initiated in 2008 and is ongoing. Another study on human factors analysis of road weather advisory and control information was recently completed. The objectives of the human factors study were to identify traveler requirements for weather information (both pre-trip and en route) and determine the most effective messages and methods for communicating road weather information. A major product from this study is the *Guide for Designing Road Weather Information Messages and Dissemination Methods*, which is being tested and evaluated beginning in 2010.

In 2009, the RWMP completed a research project to develop weather-sensitive traffic prediction and estimation models and incorporate them into existing traffic estimation and prediction systems. Starting in 2010, these models are being tested and evaluated in some major U.S. cities.

The RWMP is also undertaking a research study to review and document the state of the practice in Weather Responsive Traffic Management (WRTM) strategies, and identify potential improvements to existing strategies. This task will develop and test improved or new WRTM strategies as well as assess their benefits. Finally, the WRTM project team has been working with traffic management centers (TMC's) around the country in using the FHWA *Weather Integration Self-Evaluation Guide for TMC's* to conduct self-assessments of their weather integration needs and identify strategies for improving the use of weather information in their daily operations.

Federal Railroad Administration (FRA)

The FRA supports research on improving the collection, dissemination, and application of weather data to enhance railroad safety through its Intelligent Weather Systems project, which is part of the Intelligent Railroad Systems program within FRA's Railroad System Safety research program. 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 onboard 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. These intelligent systems will provide advance warning of weather-related hazards such as flooding; track washouts; snow, mud, or rock slides; high winds; fog; high track-buckling risk; or other conditions that require adjusting train operations or action by maintenance personnel.

Weather data collected from railroad sensor networks could also be forwarded to weather forecasting centers to augment their other data sources. Installation of a 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.

NOS Marine Transportation Research

Ocean Systems Test and Evaluation Program (OSTEP). OSTEP facilitates the transition of new oceanographic and meteorological sensors and systems to an operational status, in support of the NWLON and PORTS programs. OSTEP tests instruments to ensure that they meet NOS requirements, develops operational deployment and implementation processes, and establishes quality-control criteria. OSTEP also develops defensible justification for the selection of instruments used for CO-OPS installations, and subsequent validation procedures for the devices traceable to U.S. National Standards or other accepted standards. Recently, a joint test with the USACE culminated in the selection of a visibility sensor deemed suitable for operations in a marine environment, and the first sensor was successfully installed in FY 2010. Ongoing testing of visibility sensors as part of this joint study will also provide information on ideal maintenance schedules by FY 2011. Furthermore, OSTEP is conducting a short-term wind sensor study with USACE into FY 2011 to explore a new technology for possible deployment at NWLON and PORTS stations. This study may initiate a multiyear goal of replacing backup wind sensors with a different technology, beginning in FY 2011 at the earliest.

WILDLAND FIRE WEATHER SERVICES

For purposes of this *Federal Plan*, Wildland Fire Weather Services are those specialized meteorological services and facilities established to meet the requirements of the wildfire management community at the Federal, state, tribal, and local levels. The primary areas of service are to support the reduction of wildfire initiation potential and the mitigation of both human and environmental impacts once initiation does occur. Services can include support to first responders and land managers and climate services tailored to wildland fire management.

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

Fire Weather Services in the National Coordination Structure for Wildland Fire Management

Just as the service category for aviation weather derives from the need to understand and prepare for the influences of weather and other atmospheric conditions on the activity of flying aircraft, wildland fire weather services are needed to understand and predict the influences of weather and other atmospheric conditions on fire in the environment, particularly with the objective of assisting in the activity of managing and controlling such fires. Wildland fire weather services are therefore an integral part of the larger activity of wildland fire management.

National Wildfire Coordinating Group (NWCG)

During 2008-2009, the interagency governance and coordination structure for wildland fire management was extensively streamlined and reorganized. This restructuring strengthens the policy and program implementation role of the NWCG. There are two levels of oversight and policy coordination/strategic direction above the NWCG: the Wildland Fire Leadership Council at the most senior Federal agency level (directors of the wildland management agencies) and the Fire Executive Council (FEC) for executives of offices directly responsible for wildland fire management. The Executive Board of the NWCG includes the Fire Directors of the five Federal wildland fire management agencies: the Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), Fish and Wildlife Service (FWS), and National Park Service (NPS) in the U.S. Department of the Interior and the U.S. Forest Service in the Department of Agriculture. The Executive Board also includes representatives from the U.S. Fire Administration within the Federal Emergency Management Agency, Department of Homeland Security, and two entities with responsibility for wildfire management on non-Federal forest lands: the National Association of State Foresters and the Intertribal Timber Council.

Much of the restructuring effort in 2008–2009 focused on the system of committees and subcommittees chartered under the NWCG. The NWCG has been organized into three branches, each with a full-time Branch Coordinator: Policy, Planning, and Management Branch;

Equipment and Technology Branch, and Preparedness Branch. The NWCG committee most directly and frequently involved with capabilities for informing the wildland fire community about fire weather is the Fire Environment Committee in the Equipment and Technology Branch. Five permanent subcommittees are currently chartered under the Fire Environment Committee: Fire Weather, Fire Danger, Fire Behavior, Fire Reporting, and National Predictive Services. The last of these subcommittees oversees and provides guidance to the Predictive Services Program, which provides an important range of fire weather capabilities to the wildland fire community through the Predictive Services Units discussed below.

National Interagency Fire Center (NIFC)

The NIFC, located in Boise, Idaho, is the Nation's support center for wildland firefighting. Eight different agencies and organizations are part of NIFC: the five wildland management agencies, NOAA/NWS, the National Association of State Foresters, and the U.S. Fire Administration. Decisions are made using the interagency cooperation concept because NIFC has no single director or manager.

Entrance to the NIFC in Boise, showing the logos of the participating Federal agencies and the National Association of State Foresters.

The National Interagency Coordination Center (NICC), located at the NIFC, is the focal point for overseeing all interagency wildland fire coordination activities throughout the United States. Wildfire suppression is built on a three-tiered system of support: the local area, one of the 11 geographic areas, and finally, the national level. When a fire is reported, the local agency and its firefighting partners respond. If the fire continues to grow, the agency can ask for help from its Geographic Area Coordinating Center (GACC). When a geographic area has exhausted all its resources, it can turn to the NICC for help in locating what is needed, from air tankers to radios to firefighting crews to incident management teams.

National Predictive Services Program

Under the Predictive Services Program, meteorologists who specialize in fire weather services team with intelligence specialists and wildland fire analysts at the GACCs and the NICC to form Predictive Services Units. Each GACC and the NICC has a Predictive Services unit staffed with one or two meteorologists and an intelligence specialist. The NICC unit includes a wildland fire analyst, and some of the GACC units add a fire behavior specialist during fire season. The Predictive Services units act as centers of expertise to produce integrated planning and decision

support tools that enable more proactive, safe, and cost-effective fire management. The Predictive Services Program functions under the guidance of the National Predictive Services Subcommittee of the NWCG.

National Weather Service (NWS)

NWS Fire Weather Services support Federal, state, and local land management agencies such as the BLM and the USFS. On the national level, the NWS Storm Prediction Center issues assessments in advance of the development of critical fire weather patterns. NWS also issues a complete Fire Weather Forecast twice daily, with updates as needed. The forecast contains weather information relevant to fire control and smoke management for the next 36-48 hours. The appropriate dispatch zones and crews use this information to plan staffing levels, equipment placement, prescribed burn conditions, and to assess the daily fire danger. Once per day, NWS meteorologists issue forecasts for specific wildland observation sites for input into the National Fire Danger Rating System (NFDRS). NFDRS determines land use restrictions and informs the public of the daily fire danger via the Smokey Bear awareness campaign. The WFOs also determine if a Fire Weather Watch or a Red Flag Warning needs to be issued. These products alert the public and other agencies that conditions are creating the potential for extreme fire behavior.

Upon request, NWS also provides on-scene assistance at large wildfires or other disasters, including HAZMAT incidents, by deploying Incident Meteorologists (IMET) to work with Incident Management Teams. IMETs travel quickly to the incident site and then assemble a mobile weather center capable of providing continuous meteorological support for the duration of the incident. The IMET program is coordinated and implemented nationally by the National Fire Weather Operations Coordinator and the National Fire Weather Program Manager, located at the NIFC.

In the past two years, NWS has implemented regional digital weather files to complement currently-provided spot forecasts. The weather output enables Fire Behavior Analysts to directly input weather data into their fire gridded fire weather element forecasts to be used as input into more accurate fire danger assessments. These improvements are particularly important near zones where planned communities meet the wildland forests. FY 2010 improvements also include an improved spot forecast program, allowing spot forecast for fires, hazardous spills, search and rescue and marine/coastal incidents. In addition, NWS will continue excellent interagency relations with the wildland fire community through implementation of a new Interagency Agreement for Meteorological Services.

U.S. Department of Agriculture, U.S. Forest Service

The U.S. Forest Service uses meteorological data and interpretation skills data for decision making regarding wildland fire management. The Forest Service Fire and Aviation Management program operates a network of approximately 890 remote automated weather stations (RAWS) in a national network of over 2200 stations. The network provides real-time information which is key in the highly utilized weather information management system (WIMS) used by fire agencies across the country. The data collected is crucial to supporting active wildfire decision-making including use in the Wildland Fire Decision Support System and associated fire modeling tools as well as for decision-making for prescribed fire operations.

The program provides liaison with the Satellite Telemetry Interagency Working Group (STIWG) and its associated Technical Working Group and with the NWS, the wildland fire management agencies in the Department of the Interior (BLM, FWS, BIA, and NPS), State fire protection agencies, and the NWCG on the delivery of fire weather data and forecasting, critical for safety and effectiveness of fire fighting. The RAWS Program oversees the standards for over 2200 remote automated weather stations across the country and manages the Interagency RAWS Website to support the program. The website address is http://www.fs.fed.us/raws. These stations form the basis for the assessment of fire danger, the pre-positioning of fire fighting resources and the conducting of prescribed fire operations. The costs include maintenance support contracts, maintenance training sessions, contracts for the delivery of this information to agency personnel, fire weather forecasters, and state forestry agencies that use the data in real-time for critical decisions. An independent assessment of the RAWS network was conducted in FY 2009 and FY 2010 by the Desert Research Institute under a contract with the NWCG.

Wildland fires in the wildland-urban interface are a continuing threat to lives and property.

The agency weather program works with the National Predictive Services Group at the NIFC to provide technical support and oversight to the 10 GACCs. It also works closely with the Forest Service Research and Development staff in the oversight of the five Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) locations. This 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 both planning of wildland fire activities as well as operational decision-making.

U.S. Geological Survey

The USGS, in cooperation with the USFS, routinely provides weekly forecasts of fire danger for the conterminous US and provides these forecasts to the National Interagency Fire Center. The forecasts are derived from an integration of vegetation condition

observed from satellite and meteorological forecasts provided from the National Weather Service National Digital Forecast Database (NDFD). The NDFD forecasts provide meteorological information necessary for the calculation of live and dead fuel moisture, a critical element in determining wildland fire danger.

For active fire, the Basic Fire Behavior (BFB) and Short-Term Fire Behavior (STFB) components of the Wildland Fire Decision Support System (WFDSS) use forecasted weather from the National Digital Forecast Data (NDFD). NDFD incorporates Remote Access Weather Station location to derive forecasted weather data. This forecast information, along with geospatial data provide by the USGS are used to derive live and dead fuel moisture characteristics and wind conditions to aid in the prediction of fire behavior.

Landslides Hazards Program. Debris flows and flash floods that originate from steep watersheds burned by wildfire pose considerable hazards to downstream communities and structures. Fires throughout the western U.S. have impacted hundreds of thousands of acres of public land and made it susceptible to increased runoff and debris-flow activity. Science-based information on post wildfire debris-flow hazards is critically needed by Federal, State, and local agencies to issue warnings and to mitigate the impacts of post-fire hazards on people, their property, and natural resources. A joint NOAA/USGS, flash flood and debris flow warning system for recently burned basins in southern California was established in 2005 by linking the existing National Weather Service (NWS) Flash Flood Monitoring and Prediction (FFMP) system with rainfall intensity-duration thresholds for burned areas developed by the USGS. Such a system is being used to issue Outlooks, Watches and Warnings that are disseminated to emergency-management personnel and the public through the NWS existing protocol. The USGS has also developed models for characterizing potential post-fire debris flow susceptibility that, when compared with forecast or measured precipitation, have been used to generate maps of potential hazards in real- time, which have been disseminated to the Federal Emergency management Agency (FEMA) and the public through existing NWS protocol. The USGS has also developed models for characterizing potential post-fire debris flow susceptibility that, when compared with forecast or measured precipitation, have been used to generate maps of potential hazards in real- time, which have been disseminated to the Federal Emergency Management Agency (FEMA) and State and local agencies. Since its inception, numerous advisories have been given to residents and public officials which have resulted in saved lives and reduced property damage.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

Department of Agriculture, U.S. Forest Service

Research activities at the U.S. Forest Service serve to improve the health and use of our Nation's forests and grasslands. Forest Service Research (FSR) studies long-term effects of air pollution on forests of the Sierra Nevada Ecosystem, Cascade and coastal forests in the Pacific Northwest, Rocky Mountains, Appalachian Mountains, and the northeastern United States. Air pollution effects (primarily nitrogen and sulfur deposition and ozone) remain a serious threat to forest health in some parts of the U.S.

Although nitrogen and sulfur atmospheric deposition have been studied for many years in eastern forest watersheds, and FSR has demonstrated that increased nitrogen deposition can affect water quality and ecosystem function in western forests. FSR along with other agencies participating in the National Atmospheric Deposition Program (NADP) has been developing, in cooperation with the European Union International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests and National Forest Systems, a comprehensive approach to critical loads in selected forest ecosystems across the United States to improve knowledge of potential nationwide impacts. The inaugural project, a Critical Loads Focus Center, will begin early in fiscal 2011. 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 International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests protocol. A workshop to run these sites is being planned for early fiscal 2011. Also, a first draft of a comprehensive review and guide for calculating critical loads of nitrogen deposition was developed by FSR scientists in 2010.

Smoke from forest fires and other biomass burning is a national concern as use of prescribed fire in ecosystem management increases. Exposure of firefighters and citizens to forest fire smoke, changes in visibility and haze, and smoke contributions to regional and local air pollution are of concern. FSR is the world leader in developing emissions factors from fires and modeling its dispersion. FSR 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 potential of smoke to exacerbate particulate matter and ozone episodes. FSR has provided basic research to support states' air regulatory programs and Environmental Protection Agency's development of air quality standards. Through five Fire Consortia for Advanced Meteorological Modeling of Smoke (FCAMMS) (www.fs.fed.us/fcamms), real-time smoke and fire weather research products are supplied nationally to fire and air quality managers continuously with predictions of impacts made out to 7 days in the future. These modeling efforts are now being coordinated with more closely with NOAA Fire Weather research with a coordinating workshop scheduled to take place in early FY 2011.

National Aeronautics and Space Administration (NASA)

NASA supports innovative, near-term demonstrations of its scientific results, technology developments, and satellite observations for societal benefit. These projects serve as a bridge between NASA-generated data and knowledge and the information and decision-making needs of public and private organizations. End-users of NASA's products are able to apply Earth observations and model results to support activities that influence productivity, enhance quality of life, and strengthen the economy.

The Wildfire Research and Applications Partnership (WRAP) project is a collaboration between NASA, the U.S. Forest Service, NIFC, and California Department of Forestry and Fire Protection (CalFire) to explore, develop, mature, demonstrate and operationalize NASA data, models, and technologies to improve wildfire observations and management practices in the United States. The goals are to improve on existing capabilities and models employed by the National Interagency Command Center and the Incident Command Structure, which are responsible for day-to-day wildfire management and suppression. WRAP is transferring a

number of capabilities to operations including the Collaborative Decision Environment, real-time data telemetry, sensor systems, small unattended aerial vehicle use for tactical mapping, and procurement of new manned aircraft assets to further support the nation for disaster response. Technologies enhanced through WRAP include the NASA Autonomous Modular Sensor (AMS) airborne imaging spectrometer, collaborative software tools for improved wildfire intelligence and visualization, unique unattended platform, real-time data communications and sensor web technologies. AMS is capable of peering through thick smoke and haze to record hot spots and the progression of wildfires over a lengthy period. AMS observations are transmitted in real-time to the incident command posts to assist firefighting situational awareness. In 2010 and 2011, WRAP will adapt USFS aircraft to fly NASA wildland fire sensors.

OTHER SPECIALIZED SERVICES

For purposes of this *Federal Plan*, Other Specialized Services include weather and climate information services and facilities established to meet the special needs of user agencies or constituencies not included in basic services or the preceding service categories. This service category includes any efforts to integrate the social sciences into meteorological operations, applications, and services not already described in the preceding sections.

OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

National Aeronautics and Space Administration (NASA)

The National Aeronautics and Space Administration (NASA) provides operational weather support to spaceflight operations through the Space Operations Mission Directorate (SOMD).

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 between NASA, the Department of Defense (DOD), and the Department of Commerce (DOC), and includes KSCWO, NASA's Marshall Space Flight Center (MSFC) and Johnson Space Center (JSC), the DOD's US Air Force (USAF) 45th Space Wing, and the DOC's 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 Cape Canaveral Air Force Station (CCAFS) in Florida and also land at Edwards Air Force Base (AFB) 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, Vandenberg AFB in California, NASA Wallops Flight Facility in Virginia, and the US 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 Department of Transportation (DOT) Federal Aviation Administration (FAA) utilizes the same LLCC at commercial spaceports.

In FY 2010, the KSCWO conducted the following activities:

- Supported Space Shuttle missions: STS-129 through STS-132
- Supported launch of Ares 1-X
- Supported the Constellation program through infrastructure and requirements concept studies of Ares 1 and Ares 1-X rockets and Orion Crew Exploration Vehicle (CEV)
- Completed documenting the history and rationale behind the lightning launch commit criteria
- Supported NASA ELV launches from the Eastern and Western ranges, as well as commercial and DOD launches from the Eastern Range

In FY 2011, the KSCWO will perform the following activities:

- Continue to support the Space Shuttle and ELV programs
- Support the Constellation program or its successors or replacements, and continue support for planning and design of the test flight programs
- Support the transition and retirement activities of the Space Shuttle Program
- Work with the Eastern Range to define the requirements and infrastructure for weather support at KSC and CCAFS in the post-Shuttle era

Spaceflight Meteorology Group (SMG)

The SMG is located at NASA Johnson Space Center (JSC). In FY 2010, the SMG conducted the following activities:

- Supported Space Shuttle missions STS-129, STS-130, STS-131, and STS-132 with weather analyses, forecasts, consultations, and documentation
- Supported the International Space Station with daily Soyuz contingency landing forecasts for worldwide locations
- Provided an average of 35 unscheduled face-to-face weather briefings per Space Shuttle flight, in addition to normal activities
- Supported Constellation program Ares 1-X project, including upper-air wind forecasts for the Ares 1-X launch in October, 2009
- Supported the Constellation Program with weather requirements for landing and recovery of the new Orion spacecraft and its crew
- Provided weather support and consultation for the Hypersonic Thermodynamic Infrared Measurement (HYTHIRM) project based at NASA Langley
- Provided weather support for the HAYABUSA project, a Japanese Aerospace Exploration Agency mission “to bring back samples from an asteroid and investigate the mysteries of the birth of the solar system,” based at NASA Ames
- Served on multiple panels and working groups supporting the Constellation program

- Increased hurricane support to JSC for post-center-closure and recovery phase in response to post-Hurricane Ike update to JSC requirements
- Hosted and facilitated NWS Southern Region HQ Decision Support Program (DSP) team for a consultation and benchmarking visit to JSC and SMG
- Hosted and facilitated NWS Heads of Training Group (HOTG) for a consultation and benchmarking visit to JSC and SMG, regarding simulations and decision-support strategies
- Provided mentoring and training to Southern Region NWS offices for developing local simulations
- Collaborated with the Applied Meteorology Unit (AMU) on technique development
- Supported several educational outreach events

FY 2011 activities for the SMG include the following:

- Support Space Shuttle missions with weather analyses, forecasts, consultations, and documentation
- Support Space Shuttle simulations with Mission Control Center
- Support the International Space Station with daily Soyuz contingency landing forecasts for worldwide locations
- Provide inputs for the weather requirements for landing and recovery of the Orion spacecraft
- Provide weather support and consultation for the HYTHIRM project based at NASA Langley for STS-133, STS-134, and the Space-X capsule re-entry
- Provide local weather support (including hurricane support) to JSC and potentially to other NASA centers (excluding KSC)
- Provide shuttle weather history archiving in preparation for end of shuttle program
- Provide continued educational outreach

Marshall Space Flight Center (MSFC)

The Natural Environments Branch (NEB) develops and implements weather support requirements for the Space Shuttle and other programs, including development and evaluation of launch constraints. The Earth Sciences Branch (ESB) conducts research primarily focused on the Earth's hydrological cycle.

FY 2010 activities of the NEB and ESB included the following:

- The NEB supported four Space Shuttle missions: STS-129 (16 November 2009), STS-130 (8 February 2010), STS-125 (5 April 2010), and STS-127 (14 May 2010) by performing day-of-launch analyses of upper air winds for evaluation of Space Shuttle vehicle ascent loads.

- The NEB developed or improved wind climatological data sets for safety margin analyses and day-of-launch procedures, relating to upper-air wind requirements for the Space Shuttle and Constellation programs.
- The NEB provided day-of-launch upper-air wind monitoring for the Ares I-X vehicle in 28 October 2009.
- The ESB continued to developed scan strategies and operations concepts for the new Doppler, dual polarization 5-cm weather radar at CCAFS.

Activities for FY 2011 include the following:

- The NEB will continue to support the Space Shuttle Program by providing interpretation and updates to the terrestrial environments requirements, and upper-air wind analysis on day-of-launch in support of day-of-launch wind biasing of the vehicle's steering commands.
- The NEB will continue to develop terrestrial environments requirements to be applied to the design and development of future programs.
- The NEB will continue to develop and improve wind climatological data sets for safety margin analyses and day-of-launch procedures relating to upper-air wind requirements for the Space Shuttle and future programs.

U.S. Army Space and Missile Defense Command (USASMDC)

Support to the Ronald Reagan Ballistic Missile Defense Test Site (RTS)

Army Kwajalein Atoll, a subcommand of USASMDC, provides operational support to the RTS. The RTS meteorological services contractor provides support for range activities, including local and remote missile launches, missile weapons readiness testing, aviation and marine operations, and emergency operations.

A rocketsonde launch on Kwajalein Atoll. US Army Photo

A full suite of meteorological surface, upper air, satellite, radar, and lightning observing systems are available. Surface systems include, an intra-atoll mesonet and a Federal Aviation Administration (FAA) approved Automated Weather Observing System (AWOS), supporting range and International Civil Aviation Organization Army Airfield operations at Kwajalein. Upper air sounding systems (1680 MHz) utilizing Global Positioning System (GPS) radiosondes are located on Kwajalein and Roi-Namur. One portable GPS upper air

system (403 MHz) is available to provide soundings at remote locations. A dual-polarized Doppler S-band weather radar provides weather surveillance from Kwajalein Island, and a Doppler C-band weather radar is available for operations at Wake Island. Both are volume-scanning radars that support prediction of lightning events. Two Polar-orbiting Operational Environmental Satellite (POES) satellite receivers (one mobile) and two geostationary satellite receivers (one transportable) provide access to satellite imagery, cirrus cloud detection, and cloud height, with data processing and analysis provided through McIDAS management and display systems. A lightning detection network of four sensors is available to the RTS meteorologist at Kwajalein. A thunderstorm sensor that includes a field mill supports lightning prediction and detection at Wake Island. RTS provides rocketsondes locally and at remote locations where radar tracking can support them.

In cooperation with NASA Goddard Space Flight Center, RTS Weather continues to support global climate studies through the Tropical Rainfall Measurements Mission and the follow-on program of Global Precipitation Measurement. Solar-Earth radiation fluxes monitoring with a suite of radiation measurements systems have continued since 1989 in support of work at NOAA'S Earth Systems Research Laboratory (ESRL).

National Park Service (NPS)/Fish and Wildfire Service (FWS)

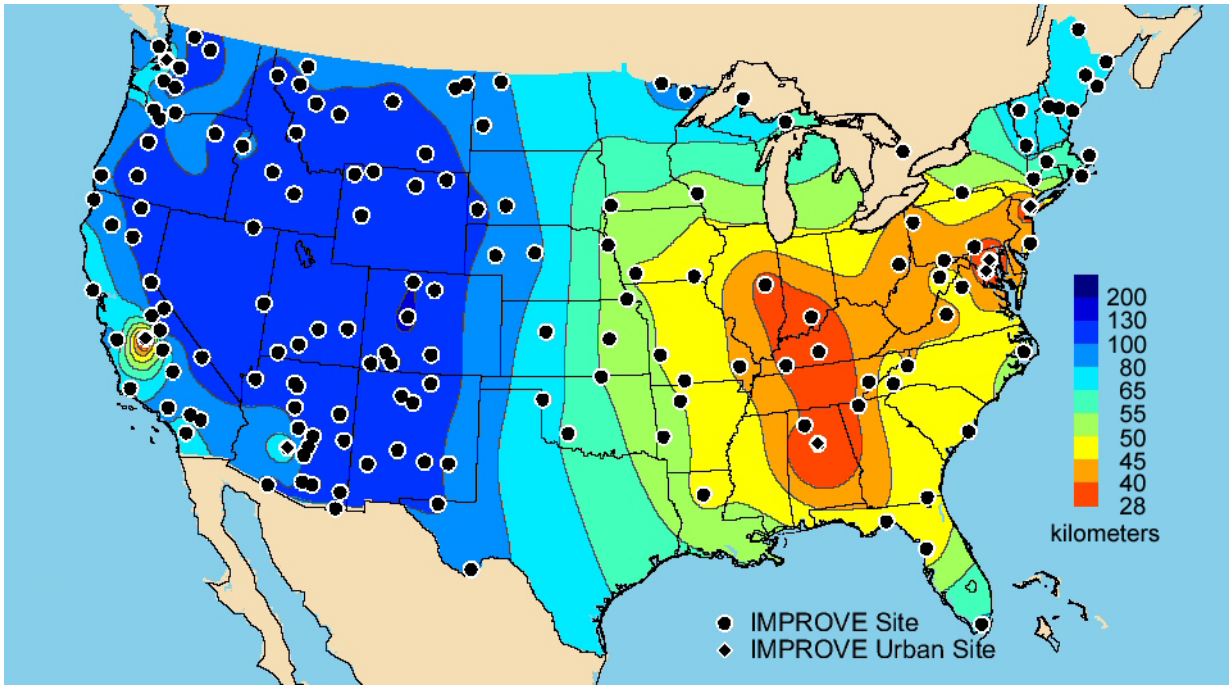
NPS Air Quality and Visibility Monitoring

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.

Joint Air Quality Monitoring

The FWS 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 United States 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 its 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 (see figure below).



Map of three-year average standard visual range (SVR) from 2005-2008, in kilometers, calculated from IMPROVE particle concentrations. Also shown are the locations of most of the IMPROVE and IMPROVE protocol sites.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NASA

Applied Meteorology Unit

The Applied Meteorology Unit (AMU) is a joint venture between KSCWO, the 45th Space Wing, and the NWS. The AMU is collocated with the 45th Weather Squadron (45 WS) located at CCAFS. The AMU develops, evaluates, and transitions weather technology into operations.

In FY 2010, the AMU performed the following activities:

- Updated the Peak Wind Tool for User Launch Commit Criteria (LCC) cool season climatologies and distributions of 5-minute average and peak wind speeds for the 45 WS and Spaceflight Meteorology Group (SMG), which had indicated that peak winds are a challenging parameter to forecast. Updated the statistics with additional data collected from 2003-2007, thereby increasing the period of record (POR) from 8 to 13 years, used new time-period stratifications, and a new parametric distribution. These modifications make the climatologies more robust and useful to operations. The AMU developed a graphical user interface (GUI) in Excel to display the statistics to the user.
- Updated the Objective Lightning Probability Tool forecast equations used in 45 WS operations with new data and new stratifications based on the progression of the lightning season instead of creating an equation for each month. Three warm seasons (May–September) were added to the POR, increasing it to 20 years (1989–2008), and data for October was included.

- Updated the Peak Wind Tool for General Forecasting used by the 45 WS to forecast the peak wind speed for the day on KSC/CCAFS during the cool season months, October-April. The period of record was expanded by two years to increase the size of the data set used to create the forecast equations, new parameters were evaluated as predictors, and the performance of the Phase I and Phase II tools were compared. The AMU developed GUIs for Excel and the Meteorological Interactive Data Display System (MIDDS).
- Developed an update for the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) for the local data integration system (LDIS) at SMG and the National Weather Service Melbourne (NWS MLB) office; updated the AMU-developed shell scripts, using the Perl programming language, that were written to govern the LDIS so that it can be easily maintained
- Developed a Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model GUI that allows forecasters to update selected parameters within the HYSPLIT model used at NWS MLB. The GUI allows easy adjustment of selected parameters on daily and emergency runs to help NWS MLB forecasters improve efficiency and reduce human error when running HYSPLIT in support of incidents involving toxic substances dispersed into the atmosphere.
- Verified the performance of the 12-km resolution North American Mesoscale (NAM) model (MesoNAM) forecasts for CCAFS and KSC via an objective analysis. The objective analysis provided the 45 WS Launch Weather Officers knowledge of the model's strength and weaknesses, resulting in improved forecasts for operations. The AMU developed a GUI using JavaScript and Hyper-Text Markup Language that can be run using a web browser.
- Updated the Severe Weather Tool in MIDDS by adding weather observations from the years 2004-2009, re-analyzed the data to determine the important parameters, and updated the tool with the new information
- Supported launch operations for four Space Shuttle, four Atlas V, three Delta IV, one Falcon 9, and one Ares I-X missions

In FY 2011, AMU activities will include the following:

- Update the Climatology of Lightning Probabilities by adding National Lightning Detection data from the 2008-2010 warm seasons (May-September) to create a 22-year lightning climatology and expand the number of sites supported by NWS MLB and SMG from 8 to 22. In addition, stratifications will be added for atmospheric stability and/or moisture parameters to help operationally separate lightning days that are more active from those that are less active within the same flow regime.
- Conduct a Vandenberg AFB (VAFB) North Base Wind Study to assess terrain effects that possibly influence wind towers during Great Basin High regimes with northeasterly winds occurring across VAFB. The study will review and analyze the synoptic conditions for those days that winds at towers 70 and 71 meet or exceed the 35 knot warning threshold.
- Update the MesoNAM verification by adding at least one year of data to the existing 3.5 year database and update the GUI with the new statistics

- Update the Severe Weather Tool in MIDDS by adding the 2010 warm season data to increase the POR to 220 years and use statistical logistic regression to develop a new forecast tool
- Modify the Peak Wind Tool for User LCC cool season climatologies by adding 3 years of observations to increase the POR to 16 years and stratify the data by atmospheric stability rather than by month. Update the Excel GUI

Environmental Protection Agency (EPA)

Air Quality Research

Meteorological support to the EPA's Office of Research and Development and Office of Air and Radiation, EPA regional offices, and to State and local agencies includes the following:

- Conducting basic and applied research in air quality modeling
- Conducting field studies for air quality model development and air quality model evaluations
- Developing and applying multi-scale and multi-pollutant air quality models for pollution control, direct and indirect exposure assessments, and emission control strategy assessment
- Reviewing of meteorological aspects of environmental impact statements, state implementation plans, and pollution variance requests
- Providing Air Quality Index forecasts to state and local agencies for health advisory warnings
- Understanding the relationships between air quality and human health
- Understanding the atmospheric loading of pollutants to sensitive ecosystems
- Understanding the interactions of global climate change and air quality
- 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, regarding 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 meteorology and atmospheric chemistry.

Research in human exposure modeling includes both micro-environmental monitoring and modeling and the 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; i.e., indoor, urban, complex terrain, mesoscale, regional, and global. Other efforts include modeling nutrient deposition to the Chesapeake Bay, mercury deposition to the Florida Everglades, and the 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, and the Pentagon were simulated in the wind tunnel to help build confidence in the modeling assessment of the source-receptor relationships for horrific events such as the one that occurred on September 11, 2001. The impacts of noise barriers and vegetation on air quality near roadways are being assessed, and improvements are being made to the EPA's AERMOOD model to better simulate the transport and dispersion of pollutants from roadways.

Over the past 25 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, and 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.

The CMAQ model (first released in June 1998) is used by Federal and state agencies, industry, and academia and is updated periodically to reflect the state-of-science. The latest version of CMAQ, which includes science enhancements and computational efficiencies, was released in September 2008. It is also intended to serve as a community framework for continual advancement and for use in conducting environmental assessments. 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 on the division web site at http://www.epa.gov/amad.

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. NWS implemented the CMAQ modeling system, to provide daily forecast guidance for ozone 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 are responsible to forecast local air quality and provide health advisory warnings.

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. The following primary objectives are directed toward this goal:

- 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
- 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 the exchange of research meteorologists and research results, pertaining to meteorological aspects of air pollution. For example, agreements are currently in place with Canada, the United Kingdom,

Greece, Japan, Korea, China, India, and Mexico, and with several European countries under the NATO Committee for Science for Peace (SPS).

National Park Service (NPS)/Fish and Wildfire Service (FWS)

NPS Air Quality Research

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

The NPS is conducting research in the area of atmospheric nitrogen loading to high elevation ecosystems in the Rocky Mountains, which have documented effects from nitrogen deposition. Measurements taken at Rocky Mountain National Park, in Colorado, indicate that routine monitoring networks may underestimate nitrogen deposition on the order of 30 percent by not analyzing for organic nitrogen and not routinely monitoring for ammonia gas. Source apportionment analyses indicate that under high loadings in the spring season, much of the nitrogen deposited at the park originates in the urban and agricultural areas of Colorado to the east of the park. By contrast, nitrogen loadings during the summer months had a significant contribution from Colorado, but higher loadings from source regions out of the state. The NPS is continuing this line of research in Grand Teton National Park in Wyoming.

APPENDIX A
ACRONYMS

4-D Weather SAS	4-Dimensional Weather Single Authoritative Source
ABLE	Atmospheric Boundary Layer Environment
ADA	Air Domain Awareness
AFRC	Air Force Reserve Command
AFWA	Air Force Weather Agency
AIRMAP	Atmospheric Investigation, Regional Modeling, Analysis and Prediction
AIRS	Atmospheric Infrared Sounder [NASA satellite instrument]
AMS	American Meteorological Society
AMSR	Advanced Microwave Scanning Radiometer
ANL	Argonne National Laboratory
AOC	[NOAA] Aircraft Operations Center
AOML	Atlantic Oceanographic and Meteorological Laboratory
ARL	[NOAA] Air Resources Laboratory
ARS	Agricultural Research Service
ARW	Advanced Research WRF [model]
ATD	atmospheric transport and diffusion
AWIPS	Advanced Weather Interactive Processing System
BASC	Board on Atmospheric Sciences and Climate
BCAL	Boise Center Aerospace Laboratory
BLM	Bureau of Land Management
BMS	[NWR] Broadcast Management System
BNL	Brookhaven National Laboratory
BonD	Battlespace on Demand
C2	command and control
C4I	command, control, communication, computers, and intelligence
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CASA	Collaborative Adaptive Sensing of the Atmosphere
CCSP	U.S. Climate Change Science Program
CDFS	Cloud Depiction and Forecast System [AFWA model]
CECOM SEC	[U.S. Army] Communications-Electronics Command Software Engineering Center
CEISC	Committee on Environmental Information Systems and Communications
CERIS	Coastal, Estuary Resource Information System
CESORN	Committee on Environmental Services, Operations, and Research Needs
CENR	[NSTC] Committee on Environment and Natural Resources
CENRS	[NSTC] “Committee on Environment, Natural Resources, and Sustainability
CI-FLOW	Coastal-Inland Flood Observation and Warning
CIOS	Committee for Integrated Observing Systems

CLIVAR	Climate Variability and Predictability Experiment
CNES	French Space Agency Centre National d'Etudes Spatiales
CNMOC	Commander, Naval Meteorology and Oceanography Command
CONUS	continental United States
COPC	Committee for Operational Processing Centers
CORMS AI	Continuous Operational Real-time Monitoring System
COSMIC-2	Constellation Observing System for Meteorology Ionosphere and Climate-2
CRS	Console Replacement System
CSESMO	Committee for Space Environmental Sensor Mitigation Options
DAC	[AOML] Data Assembly Center
DAMPS	Distributed Atmospheric Modeling Prediction System
DAPE	Data Acquisition, Processing, and Exchange
DATMS	Defense Information Switched Network Asynchronous Transfer Mode System
DCGS-A	Distributed Common Ground System-Army
DEM	digital elevation model
DHS	U.S. Department of Homeland Security
DMSP	Defense Meteorological Satellite Program
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
DSCOVR	Deep Space Climate Observatory
DTC	Developmental Test Center
DWSS	Defense Weather Satellite System
EcoFOCI	Ecosystem-Fisheries Oceanography Coordinated Investigations
EdIWG	[CCSP] Education Interagency Working Group
EOS	[NASA] Earth Observing System
EPA	U.S. Environmental Protection Agency
EMC	[NOAA/NCEP] Environmental Modeling Center
EPS	Ensemble Prediction System
ESRL	Earth System Research Laboratory
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration
FAR	false alarm rate
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FNMOC	Navy Fleet Numerical Meteorology and Oceanography Center
FPAW	Friends/Partners in Aviation Weather
FRP	full-rate production

FTE	full-time equivalent
FY	fiscal year
GEOSS	Global Earth Observation System of Systems
GFDL	Geophysical Fluid Dynamics Laboratory [NOAA-associated]
GFO	[Navy] Geostat Follow-On [mission]
GLD	Global Lagrangian Drifters
GLERL	Great Lakes Environmental Research Laboratory
GMAO	Global Modeling and Assimilation Office [at GSFC]
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GPS-Met	GPS-Meteorology
GSD	[ESRL] Global Systems Division
GTS	Global Telecommunications System
HALE	high altitude, long-endurance [UAS]
HFIP	Hurricane Forecast Improvement Project
HHWWS	Heat Health Watch Warning Systems
HMR	[Nuclear Regulatory Commission] hydrometeorological report
HMT	Hydrometeorological Testbed
HRD	[NOAA/OMAO] Hurricane Research Division
HWDDC	Hazardous Weather Detection and Display Capability
HWRF	Hurricane Weather Research and Forecasting
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
IFEX	Intensity Forecast Experiment
IHC	Interdepartmental Hurricane Conference
IM	incident meteorologist
IMETS	Integrated Meteorological System
IMAAC	Interagency Modeling and Atmospheric Assessment Center
INL	Idaho National Laboratory
IPCC	Intergovernmental Panel on Climate Change
IPE	intelligence preparation of the environment
IRT	Independent Review Team
IT	information technology
JAG	Joint Action Group
JAG/ADM	Joint Action Group on Architecture and Data Management (
JAG/CCM	Joint Action Group for Centralized Communications Management
JAG/JUTB	Joint Action Group for Joint Urban Test Beds
JAG/LDS	Joint Action Group on Lightning Detection Systems
JAG/MD	Joint Action Group on Metadata
JAG/OCM	Joint Action Group for Operational Community Modeling

JAG/ODAA	Joint Action Group for Operational Data Acquisition for Assimilation
JAWF	Joint Agricultural Weather Facility
JCSDA	Joint Center for Satellite Data Assimilation
JET	Joint Environmental Toolkit
JHT	Joint Hurricane Testbed
JPDO	Joint Planning and Development Office
JPSS	Joint Polar Satellite System
KSC	[NASA] Kennedy Space Center
LANL	Los Alamos National Laboratory
LBSF&I	Littoral Battlespace Sensing, Fusion, and Integration
LLNL	Lawrence Livermore National Laboratory
LRP	low-rate production
MADIS	Meteorological Assimilation Data Ingest System
MALE	medium altitude, long endurance [UAS]
MAPS	Meteorological and Aeronautical Planning System
MDSS	Maintenance Decision Support System
METOC	meteorological and oceanographic
MIT	Massachusetts Institute of Technology
MPAR	multifunction phased array radar
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	memorandum of understanding
MWPI	Microburst Windspeed Potential Index
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NDBC	National Data Buoy Center
NDFD	National Digital Forecast Database
NESDIS	[NOAA} National Environmental Satellite, Data, and Information Service
NEXRAD	Next-Generation Weather Radar
NextGen	Next Generation Air Transportation System
NGDC	National Geophysical Date Center
NHC	[NCEP] National Hurricane Center
NIFA	National Institute for Food and Agriculture
NITES	Navy Integrated Tactical Environmental System
NMFS	[NOAA] National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NOP	Naval Oceanography Program

NOPC	National Operational Processing Centers Program Council
NOS	National Ocean Service
NOWCON	Network of Weather and Climate Observing Networks
NPDIA	National Plan for Disaster Impact Assessments: Weather and Water Data
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NPRB	North Pacific Research Board
NRC	Nuclear Regulatory Commission; National Research Council
NRCS	Natural Resources Conservation Service
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSPO	[Taiwan] National Space Organization
NSSL	[NOAA] National Severe Storm Laboratory
NSWP	National Space Weather Program
NSTC	National Science and Technology Council
NWLON	National Water Level Observation Network
NWP	numeric weather prediction
NWR	NOAA Weather Radio
NWS	[NOAA] National Weather Service
OAR	[NOAA] Office of Atmospheric Research
OFA	[BLM] Office of Fire and Water
OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OGC	Open Geospatial Consortium
OMAO	[NOAA] Office of Marine and Aviation Operations
OMB	Office of Management and Budget
OMI	Ozone Monitoring Instrument
ORR	Oak Ridge Reservation
OSSE	observing system simulation experiment
OSTEP	Ocean Systems Test and Evaluation Program
OSTM	Ocean Surface Topography Mission
OSTP	Office of Science and Technology Policy
OTN	[Defense Information Systems Agency] Optical Transport Network
PAR	Phased Array Radar [Program]
PARISE	Phased Array Radar Innovative Sensing Experiment
PI	product improvement
PM	program manager
PMEL	Pacific Marine Environmental Laboratory
PNNL	Pacific Northwest National Laboratory
POD	probability of detection
POES	Polar-orbiting Operational Environmental Satellite
PORTS®	Physical Oceanographic Real-Time System
PSD	[ESRL] Physical Sciences Division

PTWC	Pacific Tsunami Warning Center
PUP	Principal User Processor
R&D	research and development
RAWS	Remote Automated Weather Stations (network)
RFC	[NWS] River Forecast Center
SDR	[CENRS] Subcommittee on Disaster Reduction
SFMR	stepped frequency microwave radiometer
SMD	[NASA] Science Mission Directorate
SNL	Sandia National Laboratory
SNOTEL	SNOw pack TELemetry
SOMD	[NASA] Space Operations Mission Directorate
SOOP	Ship of Opportunity Program
SPC	[NCEP] Storm Prediction Center
SST	sea surface temperature
STAR	Center for Satellite Applications and Research
SWA	soil, water, and air
SWEF	Space Weather Enterprise Forum
T-IWEDA	Tri-Service Integrated Weather Effects Decision Aid
TAP	Technology Assessment Program
TDA	Tactical Decision Aid
TDR	tail Doppler radar
TEP	Tactical Environmental Processor
TES	Tropospheric Emission Spectrometer
TMC	traffic management center
TOMS	Total Ozone Mapping Spectrometer
TRADOC	U.S. Army Training and Doctrine Command
TSG	thermosalinograph
TTS	through-the-sensor
UAS	unmanned aircraft systems; unmanned aerial systems
UNOLS	University-National Oceanographic Laboratory System
USA	U.S. Army
USAF	U.S. Air Force
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
USN	U.S. Navy
USWRP	U.S. Weather Research Program
VORTEX2	Verification of the Origins of Rotation in Tornadoes Experiment 2
VOS	Volunteer Observing System

W&AQR	Weather and Air Quality Research
WAOB	World Agricultural Outlook Board
WC/ATWC	West Coast/Alaska Tsunami Warning Center
WDA	[AFWA] Weather Data Analysis
WFO	National Weather Service Forecast Office
WG/DIAP	Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (
WG/MPAR	Working Group for MPAR
WG/TBC	Working Group for Test Bed Coordination
WG/UM	Working Group for Urban Meteorology
WG/WIST	Working Group on Weather Information for Surface Transportation
WIDB	Weather Information Database
WMO	World Meteorological Organization
WoF	Warn on Forecast [Program]
WRF	Weather Research and Forecasting
WRIP	Weather Radio Improvement Project
WSR-88D	Weather Surveillance Radar-1988 Doppler
WWLLN	World Wide Lightning Locator Network
XBT	Expendable BathyThermograph [Program]