The Federal Plan for Meteorological Services and Supporting Research

Fiscal Year 2012

OFCM

OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH

FCM-P1-2011

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

THE INTERDEPARTMENTAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (ICMSSR)

MR. SAMUEL P. WILLIAMSON, Chairman
Federal Coordinator

MR. THOMAS PUTERBAUGH
Department of Agriculture

DR. JOHN (JACK) L. HAYES
Department of Commerce

RADM DAVID TITLEY, USN
United States Navy
Department of Defense

DR. FRED P. LEWIS
United States Air Force
Department of Defense

MR. RICKEY PETTY
Department of Energy

MR. JOEL WALL
Science and Technology Directorate
Department of Homeland Security

MR. JOHN VIMONT
Department of the Interior

MR. MARK KEHRLI
Federal Highway Administration
Department of Transportation

MR. PAUL FONTAINE
Federal Aviation Administration
Department of Transportation

DR. JONATHAN M. BERKSON
United States Coast Guard
Department of Homeland Security

DR. REID MILLER
Department of State

DR. S. T. RAO
Environmental Protection Agency

MR. PATRICK HERNANDEZ
Federal Emergency Management Agency
Department of Homeland Security

DR. RAMESH KAKAR
National Aeronautics and Space Administration

DR. MICHAEL MORGAN
National Science Foundation

MR. DONALD E. EICK
National Transportation Safety Board

MR. SCOTT FLANDERS
U.S. Nuclear Regulatory Commission

COL WILLIAM CARLE, Secretariat
Office of the Federal Coordinator for
Meteorological Services and Supporting Research

The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 2012

FEDERAL COORDINATOR FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

8455 Colesville Road, Suite 1500 Silver Spring, MD 20910
301-427-2002

FCM-P1-2011
October 2011
WASHINGTON, D.C.

Editors: Mr. Anthony Ramirez
Mr. Robert Dumont
Dr. Robert Katt
Ms. Erin McNamara
Mr. Kenneth Barnett

PREFACE

Since 1965, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) has compiled a Federal Plan that articulates the provision of meteorological services and the support for meteorological and related research by agencies of the Federal government. The 2012 Federal Plan provides Congress and the Executive Branch with a comprehensive account of proposed programs for fiscal year (FY) 2012 and a review of agency programs in FY 2011. The Federal Plan's narratives, timelines, and schedules are current as of November 2011.

This 2012 Federal Plan uses the section structure introduced in the 2011 Plan. Section 1 summarizes the resources appropriated by Congress for FY 2011 and the resources requested in the President's FY 2012 Budget. Please note that actual FY 2011 funding under continuing resolutions or eventual final appropriation bills is not described in Section 1. The budget narrative in Section 1 is organized by agency, but Tables 1.4 and 1.5 provide a service category breakout that corresponds to major service categories for purposes of cross-agency coordination and cooperation. Section 2 contains narratives on operations and programs for providing meteorological services and supporting research and development, organized by these same service categories. This organization by service categories, rather than by department or agency, more closely follows the original intent when an annual plan was first requested by Congress and the Executive Office of the President in 1963. The introductory segment of Section 2 describes the formal Federal coordination and planning process overseen by OFCM. This segment replaces and expands on the appendix describing OFCM activities that was included in recent Federal Plans prior to FY 2011. A comprehensive list of acronyms used in Sections 1 and 2 is included as the current Appendix A.

//SIGNED//

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

Table of Contents

SECTION 1
AGENCY FUNDING FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The narratives and tables in this section summarize the budgetary information for the Federal government for fiscal years (FY) 2011 and 2012. The funds shown are used to provide meteorological services and associated supporting research with service improvements as their immediate objectives. Fiscal data are current as of the end of September 2011 and are subject to later changes. The data for FY 2012 do not have legislative approval and do not constitute a commitment by the United States Government. The budget data are prepared in compliance with Section 304 of Public Law 87-843, in which Congress directed that an annual horizontal budget be prepared for meteorological programs conducted by the Federal agencies.

AGENCY BUDGET SUMMARIES

DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 2012 is $114.8 million for operations and supporting research, up 53 percent from the FY 2011 funding level. The increase in funding is mainly for research programs, with only a slight increase in funding for meteorological operations. The USDA has requested $94.2 million for research and development programs, a $39.4 million increase from FY 2011. Most of the funding increase is for the National Institute for Food and Agriculture (NIFA), due to increases in the Agriculture and Food Research Initiative (AFRI) programs in the FY 2011 appropriation and FY 2012 President's Budget. The AFRI funds 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 the 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. The Agricultural Research Service (ARS) is the USDA's chief scientific research agency. ARS conducts research on how the 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.

The FY 2012 amount requested for meteorological operations is $20.6 million, slightly up from the $20.4 million funding level in FY 2011. 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 policymakers, government agencies, and foreign buyers of agricultural products apprised of worldwide weather-related developments and their effects on crops and livestock. The 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 2012 President's Budget totals $1.021064 billion and 4,602 full-time equivalent (FTE) employees. Requested increases and decreases in funding over the FY 2011 program include the following:

- ***National Data Buoy Center (NDBC).*** NWS requests an increase of $4 million to resolve sustainment gaps in NDBC's ocean observation capabilities, which include Coastal Weather Data Buoys (CWB) and Coastal-Marine Automated Network (C-MAN) stations. NWS currently operates 101 moored weather observation buoys and 48 C-MAN stations. Over the last 8 years, system performance has trended downward to the current low (as of February 2011) of 66 percent data availability. Decreased data availability has caused large maritime data voids where no meteorological or oceanographic data is routinely sampled. The requested increase will provide operations and maintenance funding to support buoy data availability, enabling NWS forecasters to make accurate and timely marine warnings and forecasts, and to verify the accuracy of their forecasts.
- ***Global Positioning System (GPS) radiosondes.*** NWS requests an increase of $5.042 million to fully fund the acquisition cost of the GPS radiosondes for all 102 NOAA/NWS Upper Air (UA) observing stations, utilizing GPS tracking capability and GPS radiosondes. The current NWS UA operations concept, driven by the National Centers for Environmental Prediction (NCEP) modeling requirements, requires an annual quantity of over 78,000 radiosondes per year to be launched at 102 sites. Today's powerful computers and higher resolution models are capable of processing the increased number of observations, therefore producing more accurate forecasts. NOAA's upper-air network (radiosondes, wind profilers, NEXRAD, and in-flight data sensors from commercial aircraft) provides the foundation for all short-term weather predictions. The quality, timeliness, and availability of observations from this composite network directly affect NOAA's ability to meet its protection of life and property mission.

- ***Aviation Weather.*** NWS requests an increase of $26.944 million and 4 additional FTEs to fund the planned third 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) cannot accommodate the increased demand and will be saturated by 2015. 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 Joint Planning and Development Office (JPDO) partner agencies are depending on NOAA, as the Federal weather information experts, to deliver it. The 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 requested increase will support initial operational deployment of a 4-Dimensional (4-D) Weather Data Cube for aviation users and lay the foundation for the development of follow-on capabilities. The NextGen 4-D Weather Data Cube will improve access and availability of observed and forecast weather information and enable its integration into an automated, multi-agency air traffic management system.
- ***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 to 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.
- ***NWS Cooperative Observer Program (COOP).*** NWS requests a decrease of $1.2 million to COOP by phasing out approximately 1,000 COOP observing sites. The COOP Network consists of approximately 11,000 surface observing systems located throughout the United States, and the NWS is reviewing and prioritizing the existing sites as part of the plan for phasing out approximately 1,000 sites. These stations are operated by volunteer COOP observers. COOP observational data supports the NWS field operations and climate program by providing data that is used in statistical and numerical model weather and river forecast guidance; to verify our forecasts, watches, and warnings; and to compute climatic trends. Of the 11,000 COOP sites, 1,200 sites are designated as U.S. Historical Climate Network (USHCN) sites. The temperature and rain gauge sensors at current USHCN stations lack the accuracy, precision, and resolution to monitor climate trends. The USHCN sites are not located

in an optimal configuration, resulting in observing gaps—too many stations in some areas and too few in other areas. The installation of the Regional U.S. Historical Climatology Network (RUSHCN) sites will allow NWS to prioritize which 1,000 COOP sites to phase out.

- ***Telecommunications.*** NWS requests a decrease of $3.203 million for telecommunications costs because of savings attributable to administrative efficiencies realized by the utilization of the new United States General Services Administration Network contract. NWS believes it can achieve a target reduction in its telecommunications costs across all its programs. While NWS has ongoing initiatives that may reduce the need for added bandwidth and these initiatives could conceivably result in lower existing costs, the likely result is in future cost avoidance.
- ***NWS Weather and Climate Operational Supercomputing System (WCOSS).*** NWS requests an increase of $11 million to (1) transition NOAA's operational high performance computing (HPC) to a new HPC contract and (2) to continue regular improvements to numerical weather prediction (NWP) modeling applications and thereby achieve certain model-based NWS GPRA measures. The current operational HPC contract expires at the end of FY 2011. In FY 2012 and FY 2013, NOAA must transition operations to a newly competed contract, utilizing more technologically advanced supercomputing systems. During this two year period, the production of operational NWP guidance on the current supercomputers will be maintained under a bridge contract while systems under the new contract are configured to support operations. The current increase request impacts NOAA's ability to apply HPC resources to support the production of NWP guidance. WCOSS enables NWS to output approximately 28 million model fields a day for every forecast hour, including temperature, winds, and humidity as a function of pressure. The model-based guidance underpins the provision of most of NWS products and services to the Nation by providing models and model-based estimates of both current and future states of the Earth's environment. Decision makers at all levels rely on this credible information at finer scales to support strategies to protect the lives and livelihoods of American citizens and to support commerce.
- ***NEXRAD Product Improvement (NPI).*** NWS requests a planned decrease of $2.157 million to reflect the nearing completion of the NEXRAD Product Improvement (NPI) program. The NPI program focused on shared agency (NWS, FAA, and the United States Air Force Weather Agency) requirements to effect synergistic solutions. For example, external FAA radar data are provided to NWS forecast offices to address coverage issues and provide backup data sources. NPI science improvements have made significant improvements in NEXRAD performance, products, and data leading to increased warning lead time for tornados, lower false alarm rate for severe weather warnings, and more accurate hail and precipitation amount forecasts.
- ***Complete and Sustain NOAA Weather Radio (NWR).*** NOAA requests a decrease of $5.406 million for NWR.. This planned decrease reflects the completed funding for the deployment of the NWR Broadcast Management System (BMS) and associated hardware at all 122 Weather Forecast Offices (WFO). NWR 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.
- ***NOAA Profiler Network (NPN).*** NWS requests a decrease of $2.020 million to extend the ongoing modernization of the 20-year old NPN to take advantage of the slip in the European Union's Search and Rescue Satellite Tracking (SARSAT) transponders aboard the (Galileo) GPS satellite constellation. NOAA is able to reduce its budget requirements as a result of this

slip. The Next Generation NOAA Profiler Network (NGNPN) contributes to NOAA's ability to provide and substantially improve upon its high quality products and services, such as those focused on enhancing public safety, transportation, water resources, wildfire management, and air quality monitoring and prediction. These observations and their associated metadata will be utilized by field meteorologists, assimilated into NOAA's numerical weather prediction models, made available to NOAA's partners in near real-time, and stored in the long-term archive for climate monitoring.

- ***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 two WFOs with modern, high-efficiency (green) units. Specifically, increased funding completes the St. Paul Island, Alaska, upper-air inflatable shelter, the Weather Service Office Koror renovations, and two HVAC replacements at WFOs with newer energy efficient models.

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

With the technical transfer of programs to the new Climate Service line office, NOAA/NESDIS, which is proposed to become the National Environmental Satellite Service (NESS), requests an increase of $727.891 million for a total of $2.015426 billion and 558 FTEs for the FY 2012. The cost of the technical transfer associated with the creation of the new Climate Service line office is $108.365 million and 258 FTEs. Additionally as part of this reorganization, $2.622 million and 11 FTEs are proposed to be transferred from the NOAA Library to the Office of the Chief Information Officer.

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.

The Systems Acquisition sub-activity includes the following budget line items for FY 2012:

- Polar Operational Environmental Satellite Systems (POES) NOAA Polar K-N' (Base Funding: 22 FTEs and $43,135,000). NOAA requests a decrease of $8.319 million and 0 FTE for a total of $34.816 million and 22 FTEs for the continuation of the POES program, and continued support for the MetOp program. The revised funding requirement represents recently identified savings as a result of the successful launch of the last POES satellite, NOAA-19, in February 2009.

- Joint Polar Satellite System (JPSS) (Base Funding: 61 FTEs and $382.2 million). NOAA requests an increase of $687.8 million and 0 FTE for a total of $1.07 billion and 61 FTEs to continue development of JPSS instruments, the ground systems, and the spacecraft for the afternoon orbit for the JPSS program. The JPSS program continues a number of management and acquisition reforms initiated in FY 2010 to deliver polar observations necessary to meet both the civil and military needs for weather and climate information. To implement the

restructured JPSS program as directed by Executive Office of the President in February 2010, NOAA will oversee program management while NASA will provide technical management as the acquisition agent. NOAA and NASA will share the mission success responsibility. Mission success includes building all instruments, launching the spacecraft, algorithm development, ground systems development, and all other program-related activities that are essential to the success of the JPSS program.

- Jason-3 (Base Funding: $20 million). NOAA requests an increase of $33 million for a total of $53 million to provide continuity of precise measurement of sea-surface heights for applications in ocean climatology and ocean weather. Jason-type satellite altimetry is the only proven technique for monitoring global sea-level rise—a key indicator of climate change. Jason-2 continues the systematic collection of sea-level observations initiated by TOPEX/Poseidon in 1992. The Jason-3 satellite will be functionally equivalent to the Jason-2 satellite.

- GOES-N (Base Funding: $53.945 million). NOAA requests a decrease of $19.978 million for a total of $33.967 million for the GOES-N Series program. The funding decrease re-aligns the GOES-N Series total program to support handover of GOES-15 from NASA to NOAA and provides technical management, maintenance, and operations of the on-orbit assets.

- GOES-R (Base Funding: 46 FTEs and $667.5 million). NOAA requests a decrease of $50.11 million for a total of $617.39 million to provide continued satellite engineering development and production activities for GOES-R and GOES-S, and to introduce development activities for the option satellites: GOES-T and U. This budget request for FY 2012 is for a four-satellite GOES-R (GOES-R, S, T, and U) program with enhanced capabilities above the current GOES-N, O, and P Series.

- Restoration of Climate Sensors (Base Funding: 0 FTE and $0). NOAA requests $30.4 million in FY 2012 to support the continued development of Clouds and the Earth's Radiant Energy System Flight Model 6 (CERES FM-6) and the Total Solar and Spectral Irradiance Sensor (TSIS). This request continues the development of the climate sensors to be incorporated into the JPSS program. Specifically, funds support the continued development of CERES FM-6 and TSIS instruments. The sensors under development are based on the NASA Earth Observing System (EOS) heritage designs to maintain the data continuity started by EOS that is required to accurately assess long-term changes in the Earth's climate. NASA will be NOAA's acquisition agent in procuring the Climate Sensors and will hold the contracts with vendors, under an Interagency Agreement. NOAA, however, will retain overall program management responsibility.

- Constellation Observing System for Meteorology Ionosphere and Climate-2 (COSMIC-2) (Base Funding: 0 FTE and $0). NOAA requests $11.3 million to collaborate with the Taiwan National Space Organization (NSPO) for the launch of 12 satellites which will provide replenishment and operational upgrade to the current COSMIC constellation.

- Deep Space Climate Observatory (DSCOVR) (Base Funding: 0 FTE and $0). NOAA requests $47.3 million in FY 2012 to maintain continuity of solar wind data used for geomagnetic storm

warnings by refurbishing the DSCOVR satellite and developing a Coronal Mass Ejection (CME) imager.

Office of Oceanic and Atmospheric Research (OAR)

Requested FY 2012 funding for Weather and Air Quality Research (W&AQR) is $53.7 million within OAR and an additional $22.6M within the weather-oriented components of the newly proposed NOAA Climate Service (CS), which previously has been reported under the OAR W&AQR labs that are proposed for transfer to the new CS. This amount represents a net increase of $12.4 million or 19.4 percent from the FY 2011 amount estimated at the time of the FY'12 President's Budget. Increases of $17.1 million consist of funds to: partially cover inflationary cost increases within base programs ($1.4 million), enhance the Multi-Function Phased Array Radar (MPAR) Program ($6.0 million) and fund new initiatives for wind energy ($2.0 million) and water resources ($7.7 million). Proposed decreases of $4.9 million result from reductions to Unmanned Aircraft Systems ($3.0 million), Nutrient and Mercury Speciation Research (-$0.6 million), and the THORPEX Program (-$1.3 million).

National Ocean Service (NOS)

The FY 2012 budget provides $28.979 million to 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.

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

Office of Marine and Aviation Operations (OMAO)

OMAO supports meteorological activities by collection of related data from ships and aircraft. The FY 2012 President's Budget request of $30.858 million represents a 6.8 percent decrease from the FY 2011 appropriation and 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 two primary categories: general operations and investment and research. The total AFWA weather operations and research funding for FY 2012 is $187.9 million. Additionally, the USAF provides resources for space-based environmental monitoring development and operations managed by Air Force Space Command, including the Defense Meteorological Satellite Program (DMSP), the Defense Weather Satellite System (DWSS), and the Space Situational Awareness Environmental Monitoring (SSAEM).

Operations

The operations support portion of AFWA's FY 2012 budget is $156.8 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. AFWA employs over 1,198 military and civilian personnel to conduct these activities at more than 22 locations worldwide. Approximately 71 percent of personnel specialize in weather; the remainder includes communications, computer, information technology, program management, program analyis, administrative, and logistics specialists.

Supporting Research

The total AFWA budget for meteorological-related research during FY 2012 is $31.1 million. As part of AF Smart Operations 21st Century (AFSO21), Air Force Weather (AFW) is investing in modernized environmental prediction technologies and global information grid technologies that enhance automation and save resources. In addition, AFW is investing in the following efforts in FY 2012 and beyond:

- ***Joint Environmental Toolkit (JET).*** JET will eliminate redundancies and inefficiencies in current systems by extending, consolidating, and/or replacing the Operational Weather Squadron (OWS) Production System-Phase II (OPS II), the New-Tactical Forecast System (N-TFS), and the weather effects decision aids portion of the Integrated Meteorological System (IMETS). JET also provides software components for the Defense Common Ground System – Army (DCGS-A).

- ***Weather Research and Forecast (WRF) model.*** WRF advances, as well as WRF-Chem (taking into account chemical constituents), such as with the Land Information System (LIS—a collaborative effort with NASA) and WRF coupling, will improve forecasting performance in the low levels of the atmosphere. This will allow AFW forces to provide better battlespace characterization for missions that include, but not limited to, 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 sensing capability for space weather.

- ***Cloud Depiction and Forecasting System (CDFS) II improvements.*** Improving CDFS techniques by increasing the resolution, integrating available satellite (to include non-traditional METSAT) into the cloud analysis, using a new cloud interpretation and assimilation schema, incorporating cloud optical properties, and blending numerical weather prediction with forecast cloud advection techniques will ensure the AF continues as a center of excellence in cloud analysis and forecasting. MARK IVB data integration into cloud models will be expanded.

- ***Tactical Decision Aids (TDA).*** 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 (TAWS), Infrared Target Scene Simulation (IRTSS), 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 processing NPOESS Preparatory Project sensor and environmental data for AF and Navy exploitation for military operations and enabling JET to provide decision-quality products and information to warfighters.

- ***Air Force Weather Ensemble Prediction Suite (AFWEPS).*** AFWEPS output, at both the mesoscale and global scale, will provide better meteorological intelligence for the warfighter by objectively quantifying the forecast certainty of mission-impacting meteorological parameters to optimize operational risk management for all echelons of decision making. It will provide probabilistic algorithms for high-impact variables and to quantify biases, enabling concise, focused products.

The goals of these efforts are to provide accurate, relevant, and timely meteorological intelligence to warfighters at all levels of operations quicker and more consistently than ever before, within the decision cycle and in a manner that facilitates exploitation of the current and forecasted environmental 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 Oceanographic (METOC) Database via common-user communications, integrate with joint and coalition command and control and mission planning systems, and provide the machine-to-machine data exchange for assimilating METOC and C4ISR data to meet operational and tactical mission planning and execution requirements.

United States Navy (USN)

The U.S. Navy FY 2012 budget request for meteorological programs is $79.3 million; made up of $69.8 million for operations and $8.5 million to support enabling research.

Naval Oceanography Program (NOP)

NOP is the elite, world-class maritime science and service program. It provides support in the global maritime regions around the globe, with unchallenged capabilities in the littorals and arctic. 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. Navy and Marine Corps METOC personnel provide for safe space, aviation, surface, and submerged movement, maneuver, and navigation in support of naval, joint, and combined forces, operating around the globe. This is done with a cadre of highly trained military and civilian personnel, educated in both sciences and warfighting services. 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 while 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/N6E) sponsors programs in five closely related disciplines: meteorology, oceanography, space, maritime domain awareness, and positioning, navigation, and timing (PNT). All are used to protect ships, aircraft, fighting personnel, other platforms (manned and unmanned), 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. Two high-profile elements of the NOP, Battlespace on Demand and Littoral Battlespace Sensing, are discussed in Section 2, in the subsection of Military Services on Navy Products and Services.

Operational Support

Naval METOC support starts with sensing the battlespace without being adversely affected by the 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. NITES-Fielded is a tactical environmental support system which collectively refers to all five variants. 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 time frame.

The Navy is developing a follow-on system, called NITES–Next, to increase the capabilities for ashore, afloat, and mobile METOC support to naval tactical operations and to 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 and build a System of Systems to support all joint warfighters and peace-keeping missions, including homeland defense.

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 HWDDC and TEP systems will be based off common modular weather processing algorithms and will have similar data product and display capabilities. Essentially, they represent one common set of processing algorithms applied to two different radars. The differences in capabilities supported by the systems are driven by the differences in the individual radars.

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

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. The 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 updated *Naval Operations Concept 2010* provide that vision. They align our efforts, accelerate our progress, and realize the individual and aggregate 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 estimates a $17.5 million requirement for operational support and $13.6 million requirement for research and development in FY 2012. Funding for operational support will decrease 4 percent while funding for research will decrease 15 percent from FY 2011 to FY 2012. Staffing levels decreased slightly for FY 2012, due mainly to reorganization at the US Army Fires Center of Excellence at Ft. Sill, OK.

Army monies for meteorology are spent on research and development related to the Army mission; the development, production, and maintenance of Army meteorological systems; staff meteorological functions at selected headquarters; 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 the development of meteorology policy; the coordination of meteorological support within the Department of the Army and with other Department of Defense and Federal agencies and organizations; and the development of 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). The USAF provides one full-time staff weather officer to serve as a liaison between the AF and the Army Staff. Headquarters, U.S. Army North employs one civilian meteorologist to address meteorological issues at its headquarters. Forces Command, U.S. Army Europe, Eighth U.S. Army, U.S. Army Pacific, and U.S. Army South have either active component, reserve component, or civilian Air Force meteorologists who conduct meteorological staff services at these locations. TRADOC employs both Army and Air Force personnel to manage its meteorological-related activities.

The Distributed Common Ground System–Army (DCGS-A) is the Army's premier intelligence, surveillance, and reconnaissance (ISR) enterprise for the analysis and processing, exploitation, and dissemination (PED) of information and intelligence data across all echelons. The Integrated Meteorological System (IMETS) Project Office transitioned to PM DCGS-A in 2007 to become DCGS-A Weather Services. Current work includes the testing and integration of new weather capabilities such as the Air Force Joint Environmental Toolkit (JET) into DCGS-A. Maintenance and

support for the existing fielded IMETS hardware will continue until these systems are replaced by DCGS-A.

In FY 2011, the Army received funding for the Meteorological Measuring Set-Profiler (MMS-P) artillery system, also known as the Profiler Block I system. This funding was used to support new equipment training and fielding, hardware and software upgrades, and technical support for the Block I systems. The Army requested additional funding in 2012 to support the continuation of new equipment training and fielding for all remaining Profiler Block I systems, the fielding of the Global Broadcast System (GBS) Modification to replace the Tactical Very Small Aperture Terminal satellite link, and hardware and software upgrades and technical support for the Profiler Block I systems. The Army received Research, Development, Test and Evaluation (RDT&E) funds in 2011 for the development of the CMD-P AN/GMK-2 (Profiler Block III) system, to include software analysis efforts for accuracy improvements; migration efforts, leading to a single operating system hosted on one computer; the delivery of eight production representative systems; and the conduct of technical testing. The Army requested additional 2012 RDT&E funds for the completion of CMD-P AN/GMK-2 development efforts initiated in 2011 and the conduct of Limited User Test and Austere Environmental Testing of the eight production representative systems. Procurement for the Block III systems is scheduled to begin in FY 2013.

Weather equipment maintenance and training costs at the Artillery school accounted for the majority of weather-related expenditures within TRADOC. Funds were programmed for operations support related to training development, instructor/support personnel, logistics (expendable supplies), and repair costs for artillery meteorological systems at the US Army Field Artillery School (USAFAS). Funding was also allocated to support development of weather requirements and doctrine, along with training on Army tactics, techniques, and procedures for Air Force weather personnel at the US Army Intelligence Center of Excellence at Ft. Huachuca, AZ. Maintenance and servicing of five automated surface observing sensor systems and two pole-mounted Tactical Meteorological Observing Systems at Ft Rucker, AL, accounted for the remainder of TRADOC weather-related spending.

Elsewhere in the Army, budgets for meteorological operations and research do not change significantly from FY 2011 to FY 2012. Within the Army Materiel Command, the Army Research Laboratory (ARL) continued its research and development efforts in basic meteorology. After undergoing a modest reduction in funding from FY 2010 to FY 2011, ARL anticipates a slight increase in research funding for FY 2012. The Army Test and Evaluation Command's meteorology program budget will remain relatively stable from FY 2011 to FY 2012, as will the weather operations budget for the Space and Missile Defense Command.

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 2012, the requested funding level is $28.5 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 from Coast Guard cutters. 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)

Bureau of Land Management

The Bureau of Land Management (BLM) funds two principal programs—the soil, water, and air (SWA) program and the fire weather activities of the Office of Fire and Aviation (OFA).

Soil Water and Air Program (SWA). When existing monitoring networks are not sufficient to meet the needs for air-resource-related information, the BLM, within the SWA program, 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 $1.36 million on such efforts in FY 2012. This total includes $120,000 to operate a series of RAWS stations equipped with additional instruments to measure soil moisture and winter precipitation not required for fire monitoring; $50,000 to maintain eight stations in the NRCS SCAN network; $65,000 to operate six NADP sites; $250,000 on other efforts such as downscaling climate models and assessing the response of aquatic ecosystems to reduced groundwater discharge from climate change impacts; and $875,000 for labor and logistics to support climate and weather data collection efforts by BLM resource management staff.

Office of Fire and Aviation Program (OFA). OFA funding for FY 2012 is $3.513 million, which represents BLM support for meteorologists at the National Interagency Coordination Center (NICC) and other Geographic Area Coordination Centers (GACC) and BLM support of the Interagency Remote Automatic Weather Station (RAWS) network. An additional $1.2 million is recovered through reimbursable accounts with non-DOI agencies for RAWS support. Funded activities related to the RAWS network include maintenance, travel, transportation, services, supplies, and equipment. Some agencies incur additional costs in support of the RAWS network through commercially contracted maintenance services.

The interagency RAWS network is an important tool for wildland fire management which directly supports the protection of life and property. All affected Federal agencies within DOI participate in its acquisition, operation, and support. The BLM, in particular, has a lead role in the maintenance of the RAWS network, providing both data distribution services and equipment support. Participating agencies address common issues and coordinate efforts to ensure the collection of accurate and useful fire weather data.

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. 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.

National Park Service (NPS)

The NPS expends about $1.7 million on atmospheric research with a focus on measurements of all forms of atmospheric reactive nitrogen and on aerosol science. The goal of this research is to identify the sources of air pollution that are affecting park ecosystems and visibility and to quantify their impacts. The NPS also expends approximately $2 million in routine air quality and meteorological monitoring networks.

DEPARTMENT OF TRANSPORTATION (DOT)

Federal Aviation Administration (FAA)

For FY 2012, the FAA requested a total of $212 million for the Aviation Weather Programs, including acquisition of new systems, operations and support, supporting research, and special programs. The actual funding for Aviation Weather in FY 2011 was $201 million. For FY 2012, the FAA requested an additional $11 million—a 5.5 percent increase in total funding.

The changes are comprised of:

- An increase in Systems Development from $74.8 million to $83.1 million, reflecting new programs for NextGen (see below) which show a slight increase in reported numbers for Operations Support from $15.9 million to $16.1 million and Systems Acquisitions from $6.3 million to $6.4 million.

- An increase in Special Programs funding from $68 million in FY 2011 to $71 million for FY 2012 due to adjusted budget and projections for FY 2011 and FY 2012 which show an increase in the planned research and development budget from $35.3 million to a total of $36.0 million, as reflected in the latest NARP submission.

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

Federal Highway Administration (FHWA)

All of FHWA's funding is for applied research which is nearly $5 million dollars per year. The majority of the Road Weather Management Program (RWMP) activity involves software development and studies under the research and development category to develop decision-support systems that integrate high-resolution road weather products with transportation-oriented management strategies. It also includes $320,000 to operate and expand the *Clarus* System under system development. The

remaining special program funding is for training and administration. Due to the extended time for road construction projects, DOT does not go through an annual budget process but typically uses a six-year authorization. The latest transportation authorization for the RWMP began in 2006 and has been extended through FY 2011 with little change in funding levels. The same level of funding is expected for FY 2012.

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 2012 for directed meteorological research is about $8 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 of air pollution on human health and sensitive ecosystems. In addition, to promote excellence in environmental science and engineering, the EPA established a national research grants program and substantially increased its support for investigator-initiated research. 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 2012 as in FY 2011.

The 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 2012 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $8 million listed above for directed meteorological research.

The EPA continues 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 policies, 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 intercontinental 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 model results are being made possible by means of supercomputing and scientific visualization techniques.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

The NASA funding request for FY 2012 decreases NASA's meteorological research budget .2 percent to $1.863 billion and the operations budget decreases 18.3 percent to $5.2 million.

In FY 2011, NASA spent $6.366 million on meteorological operations and $1.866 billion on supporting research. NASA supports weather operations through the Space Operations Mission Directorate (SOMD), operational satellite weather observations though the Science Mission Directorate (SMD) Joint Agency Satellite Division (JASD), weather and climate research through the

SMD Earth Science Division (ESD), 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. On August 12, 2011, SOMD was merged with another directorate to become the Human Exploration and Operations Mission Directorate (HEO).

The SMD objective in weather and climate research is to improve the accuracy of severe weather forecasts and global climate predictions through improved 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 safety and productivity of robotic explorers.

NUCLEAR REGULATORY COMMISSION (NRC)

For FY 2012, the NRC's total planned contract expenditures of $372,000 ($32,000 for operations and $340,000 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 includes 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 also include quantifying the storm surge from severe weather events and updating the hydrometeorological reports (HMR) and methods used to estimate the effects of extreme precipitation events. During FY 2012, an additional focus will be looking at the influence of orographic features on extreme precipitation events—an aspect which was ignored in developing the original HMRs. 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 and environmental reviews.

BUDGET TABLES

Table 1 Meteorological Operations and Supporting Research Costs* by Agency

TABLE 1 Meteorological Operations and Supporting Research Costs* by Agency

(Thousands of Dollars)

	Operations			% of FY2012	Supporting Research			% of FY2012	Total			% of FY2011	% of FY2012
AGENCY	FY2011	FY2012	%CHG	TOTAL	FY2011	FY2012	%CHG	TOTAL	FY2011	FY2012	%CHG	TOTAL	TOTAL
Agriculture	20409	20555	0.7	0.6	54789	94224	72.0	4.1	75198	114779	52.6	1.5	2.0
Commerce/NOAA(Subtot)	2395437	3033306	26.6	88.4	136188	139336	2.3	6.1	2531625	3172642	25.3	50.1	55.5
NWS	976481	987978	1.2	28.8	41171	33086	-19.6	1.4	1017652	1021064	0.3	20.1	17.9
NESDIS	1359400	1986991	46.2	57.9	28152	28435	1.0	1.2	1387552	2015426	45.3	27.4	35.3
OAR	0	0	0	0	63865	76315	19.5	3.3	63865	76315	19.5	1.3	1.3
NOS	29441	28979	-1.6	0.8	0	0	0	0	29441	28979	-1.6	0.6	0.5
OMAO	30115	29358	-2.5	0.9	3000	1500	-50.0	0.1	33115	30858	-6.8	0.7	0.5
Defense(Subtot)	266889	244057	-8.6	7.1	58471	54171	-7.4	2.4	325360	298228	-8.3	6.4	5.2
Air Force	175381	156842	-10.6	4.6	32373	31084	-4.0	1.4	207754	187926	-9.5	4.1	3.3
Navy	73246	69765	-4.8	2.0	10055	9500	-5.5	0.4	83301	79265	-4.8	1.6	1.4
Army	18262	17450	-4.4	0.5	16043	13587	-15.3	0.6	34305	31037	-9.5	0.7	0.5
Homeland Security (Subtot)	27570	28500	3.4	0.8	0	0	0	0	27570	28500	3.4	0.5	0.5
USCG	27570	28500	3.4	0.8	0	0	0	0	27570	28500	3.4	0.5	0.5
Interior/BLM (Subtot)	6729	6873	2.1	0.2	1700	1700	0.0	0.1	8429	8573	1.7	0.2	0.1
BLM	4729	4873	3.0	0.1	0	0	0	0	4729	4873	3.0	0.1	0.1
SWA	1360	1360	0.0	0.0	0	0	0	0	1360	1360	0.0	0.0	0.0
OFA	3369	3513	4.3	0.1	0	0	0	0	3369	3513	4.3	0.1	0.1
NPS	2000	2000	0.0	0.1	1700	1700	0.0	0.1	3700	3700	0.0	0.1	0.1
Transportation(Subtot)	91116	93611	2.7	2.7	114700	123700	7.8	5.4	205816	217311	5.6	4.1	3.8
FAA	91116	93611	2.7	2.7	110100	119100	8.2	5.2	201216	212711	5.7	4.0	3.7
FHWA	0	0	0	0	4600	4600	0.0	0.2	4600	4600	0.0	0.1	0.1
EPA	0	0	0	0	9000	8000	-11.1	0.4	9000	8000	-11.1	0.2	0.1
NASA	6366	5202	-18.3	0.2	1866748	1863029	-0.2	81.6	1873114	1868231	-0.3	37.0	32.7
NRC	140	32	-77.1	0.0	175	340	94.3	0.0	315	372	18.1	0.0	0.0
DOE	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2814656	3432136	21.9	100.0	2241771	2284500	1.9	100.0	5056427	5716636	13.1	100.0	100.0
% of FY TOTAL	55.7%	60.0%			44.3%	40.0%			100.0%	100.0%			

*The FY 2011 funding reflects Congressionally appropriated funds; the FY 2012 funding reflects the amount requested in the President's FY 2012 budget submission to Congress.

Table 2 Operational Costs by Budget Category

This table depicts how the agencies plan to obligate their funds for meteorological operations 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 identifying small components that do not fit into these two major categories, a third category is added called "Special Programs."

TABLE 2 Operational Costs by Budget Category
(Thousands of Dollars)

	Operations Support		Systems Acquisition		Special Programs		Total			% of FY2012
AGENCY	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	%CHG	TOTAL
Agriculture	20409	20555	0	0	0	0	20409	20555	0.7	0.6
Commerce/NOAA(Subtot)	1122794	1044580	1267050	1985576	5593	3150	2395437	3033306	26.6	88.4
NWS	879582	896788	91306	88040	5593	3150	976481	987978	1.2	28.8
NESDIS	183,656	89,455	1,175,744	1,897,536	0	0	1359400	1986991	46.2	57.9
OAR	0	0	0	0	0	0	0	0	0	0
NOS	29441	28979	0	0	0	0	29441	28979	-1.6	0.8
OMAO	30115	29358	0	0	0	0	30115	29358	-2.5	0.9
Defense(Subtot)	220604	211504	46285	32553	0	0	266889	244057	-8.6	7.1
Air Force	137638	132562	37743	24280	0	0	175381	156842	-10.6	4.6
Navy	71782	68300	1464	1465	0	0	73246	69765	-4.8	2.0
Army	11184	10642	7078	6808	0	0	18262	17450	-4.4	0.5
Homeland Security (Subtot)	27570	28500	0	0	0	0	27570	28500	3.4	0.8
USCG	27570	28500	0	0	0	0	27570	28500	3.4	0.8
Interior/BLM	6729	6873	0	0	0	0	6729	6873	2.1	0.2
BLM (Subtot)	4729	4873	0	0	0	0	4729	4873	3.0	0.1
SWA	1360	1360	0	0	0	0	1360	1360	0.0	0.0
OFA	3369	3513	0	0	0	0	3369	3513	4.3	0.1
NPS	2000	2000	0	0	0	0	2000	2000	0.0	0.1
Transportation(Subtot)	15982	16100	6374	6493	68760	71018	91116	93611	2.7	2.7
FAA	15982	16100	6374	6493	68760	71018	91116	93611	2.7	2.7
FHWA	0	0	0	0	0	0	0	0	0	0
EPA	0	0	0	0	0	0	0	0	0	0
NASA	6366	5202	0	0	0	0	6366	5202	-18.3	0.2
NRC	140	32	0	0	0	0	140	32	-77.1	0.0
DOE	0	0	0	0	0	0	0	0	0	0
TOTAL	1420594	1333346	1319709	2024622	74353	74168	2814656	3432136	21.9	100.0
% of FY TOTAL	50.5%	38.8%	46.9%	59.0%	2.6%	2.2%	100.0%	100.0%		

Table 3 Supporting Research Costs by Budget Category

This table 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 2012, agencies will obligate a total of $2.28 billion in supporting research funds in the following manner: $1.67 billion to research and development, $611 million to systems development, and $2.2 million to special programs.

TABLE 3 Supporting Research Costs by Budget Category
(Thousands of Dollars)

AGENCY	Research & Development		Systems Development		Special Programs		Total			% of FY2012
	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	%CHG	TOTAL
Agriculture	54789	94224	0	0	0	0	54789	94224	72.0	4.1
Commerce/NOAA(Subtot)	125115	130993	11073	8343	0	0	136188	139336	2.3	6.1
NWS	32968	27,113	8203	5973	0	0	41171	33086	-19.6	1.4
NESDIS	28,152	28,435	0	0	0	0	28152	28435	1.0	1.2
OAR	61995	74445	1870	1870	0	0	63865	76315	19.5	3.3
NOS	0	0	0	0	0	0	0	0	0	0
OMAO	2000	1000	1000	500	0	0	3000	1500	-50.0	0.1
Defense(Subtot)	29812	32598	28659	21573	0	0	58471	54171	-7.4	2.4
Air Force	9728	12106	22645	18978	0	0	32373	31084	-4.0	1.4
Navy	10055	9500			0	0	10055	9500	-5.5	0.4
Army	10029	10992	6014	2595	0	0	16043	13587	-15.3	0.6
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	1700	1700	0	0	0	0	1700	1700	0.0	0.1
BLM (Subtot)	0	0	0	0	0	0	0	0	0	0
SWA	0	0	0	0	0	0	0	0	0	0
OFA	0	0	0	0	0	0	0	0	0	0
NPS	1700	1700	0	0	0	0	1700	1700	0.0	0.1
Transportation(Subtot)	39580	40280	75120	83420	0	0	114700	123700	7.8	5.4
FAA	35300	36000	74800	83100	0	0	110100	119100	8.2	5.2
FHWA	4280	4280	320	320	0	0	4600	4600	0.0	0.2
EPA	9000	8000	0	0	0	0	9000	8000	-11.1	0.4
NASA	1370400	1362661	495388	498133	960	2235	1866748	1863029	-0.2	81.6
NRC	175	340	0	0	0	0	175	340	94.3	0.0
DOE	0	0	0	0	0	0	0	0	0	0
TOTAL	1630571	1670796	610240	611469	960	2235	2241771	2284500	1.9	100.0
% of FY TOTAL	72.7%	73.1%	27.2%	26.8%	0.0%	0.1%	100.0%	100.0%		

Operational Costs and Supporting Research Costs by Service Category

Tables 4 and 5 reflect how the agencies plan to obligate FY 2012 operational and supporting research funds by service category. The service category definitions are described below:

Service Category Definitions

- ***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.

TABLE 4 Operational Costs by Service Category

(Thousands of Dollars)

AGENCY	Basic Services		Agriculture & Land Management		Aviation		Climate		Emergency Response & Homeland Security		Hydrometeorology & Water Resources		Military		Space Weather		Surface Transportation		Wildland Fire Weather		Other Specialized		Total	
	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012
Agriculture	0	0	1170	1225	0	0	0	0	0	0	10943	10965	0	0	0	0	0	0	8296	8365	0	0	20409	20555
Commerce/NOAA(Subtot)	2311068	2931674	0	0	11538	38593	16153	9223	0	0	10613	10669	0	0	9585	9585	29441	28979	1433	1433	5606	3150	2395437	3033306
NWS	922,047	915,875	0	0	11,538	38,593	16,153	9,223	0	0	10,119	10,119	0	0	9,585	9,585	0	0	1,433	1,433	5,606	3,150	976481	987978
NESDIS	1,359,400	1,986,991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1359400	1986991
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	0	0	0	0	0	0	0	0	0	0	0	0	29441	28979	0	0	0	0	29441	28979
OMAO	29621	28808	0	0	0	0	0	0	0	0	494	550	0	0	0	0	0	0	0	0	0	0	30115	29358
Defense(Subtot)	0	0	0	0	0	0	0	0	0	0	0	0	254872	233572	12017	10485	0	0	0	0	0	0	266889	244057
Air Force	0	0	0	0	0	0	0	0	0	0	0	0	163364	146357	12017	10485	0	0	0	0	0	0	175381	156842
Navy	0	0	0	0	0	0	0	0	0	0	0	0	73246	69765	0	0	0	0	0	0	0	0	73246	69765
Army	0	0	0	0	0	0	0	0	0	0	0	0	18262	17450	0	0	0	0	0	0	0	0	18262	17450
Homeland Security (Subtot)	0	0	0	0	0	0	0	0	27570	28500	0	0	0	0	0	0	0	0	0	0	0	0	27570	28500
USCG	0	0	0	0	0	0	0	0	27570	28500	0	0	0	0	0	0	0	0	0	0	0	0	27570	28500
Interior/BLM	0	0	1360	1360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3369	3513	2000	2000	6729	6873
BLM (Subtot)	0	0	1360	1360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3369	3513	0	0	4729	4873
SWA	0	0	1360	1360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1360	1360
OFA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3369	3513	0	0	3369	3513
NPS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2000	2000	2000	2000
Transportation(Subtot)	0	0	0	0	91116	93611	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91116	93611
FAA	0	0	0	0	91116	93611	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91116	93611
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	6366	5202	6366	5202
NRC	0	0	0	0	0	0	0	0	140	0	0	32	0	0	0	0	0	0	0	0	0	0	140	32
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	2311068	2931674	2530	2585	102654	132204	16153	9223	27710	28500	21556	21666	254872	233572	21602	20070	29441	28979	13098	13311	13972	10352	2814656	3432136
% of FY TOTAL	82.1%	85.4%	0.1%	0.1%	3.6%	3.9%	0.6%	0.3%	1.0%	0.8%	0.8%	0.6%	9.1%	6.8%	0.8%	0.6%	1.0%	0.8%	0.5%	0.4%	0.5%	0.3%	100.0%	100.0%

TABLE 5 Supporting Research Costs by Service Category

(Thousands of Dollars)

AGENCY	Basic Services		Agriculture & Land Management		Aviation		Climate		Emergency Response & Homeland Security		Hydrometeorology & Water Resources		Military		Space Weather		Surface Transportation		Wildland Fire Weather		Other Specialized		Total	
	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012	FY2011	FY2012
Agriculture	0	0	46979	86340	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7810	7884	0	0	54789	94224
Commerce/NOAA(Subtot)	130763	123597	0	0	4825	15139	0	0	0	0	0	0	0	0	0	0	0	0	600	600	0	0	136188	139336
NWS	37,371	18,972	0	0	3,200	13,514	0	0	0	0	0	0	0	0	0	0	0	0	600	600	0	0	41171	33086
NESDIS	28,152	28,435	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28152	28435
OAR	62240	74690	0	0	1,625	1,625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63865	76315
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	1500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3000	1500
Defense(Subtot)	0	0	0	0	0	0	0	0	0	0	0	0	54114	48794	4357	5377	0	0	0	0	0	0	58471	54171
Air Force	0	0	0	0	0	0	0	0	0	0	0	0	28016	25707	4357	5377	0	0	0	0	0	0	32373	31084
Navy	0	0	0	0	0	0	0	0	0	0	0	0	10055	9500	0	0	0	0	0	0	0	0	10055	9500
Army	0	0	0	0	0	0	0	0	0	0	0	0	16043	13587	0	0	0	0	0	0	0	0	16043	13587
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	1700	1700	1700	1700
BLM (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
SWA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OFA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NPS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,700	1,700	1700	1700
Transportation(Subtot)	0	0	0	0	110100	119100	0	0	0	0	0	0	0	0	0	0	4600	4600	0	0	0	0	114700	123700
FAA	0	0	0	0	110100	119100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110100	119100
FHWA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4600	4600	0	0	0	0	4600	4600
EPA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9000	8000	9000	8000
NASA	0	0	0	0	0	0	1305051	1291732	0	0	0	0	0	0	560737	569062	0	0	0	0	960	2235	1866748	1863029
NRC	0	0	0	0	0	0	0	0	175	40	0	300	0	0	0	0	0	0	0	0	0	0	175	340
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	130763	123597	46979	86340	114925	134239	1305051	1291732	175	40	0	300	54114	48794	565094	574439	4600	4600	8410	8484	11660	11935	2241771	2284500
% of FY TOTAL	5.8%	5.4%	2.1%	3.8%	5.1%	5.9%	58.2%	56.5%	0.0%	0.0%	0	0.0%	2.4%	2.1%	25.2%	25.1%	0.2%	0.2%	0.4%	0.4%	0.5%	0.5%	100.0%	100.0%

Table 6 Personnel Engaged in Meteorological Operations

Agency staff resources engaged in meteorological operations. The total agency staff resources requested for FY 2012 is 8,808, no increase to FY 2011.

Table 6 PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

(Units are Full time Equivalent Staff Years)

AGENCY	FY 2011	FY 2012	%CHG	% of FY 2012 TOTAL
Agriculture	134	124	-7.5	1.4
Commerce/NOAA (sub-total)	5562	5562	0.0	63.1
NWS	4648	4654	0.1	52.8
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	113	122	8.0	1.4
OMAO	119	104	-12.6	1.2
Defense(Subtotal)	2115	2085	-1.4	23.7
Air Force	1221	1198	-1.9	13.6
Navy	415	415	0.0	4.7
Marine Corps	370	370	0.0	4.2
Army	109	102	-6.4	1.2
Homeland Security-USCG	108	108	0.0	1.2
Interior/BLM(Subtotal)	45	44	-2.2	0.5
BLM Soil/Water/Air Program	10	10	0.0	0.1
BLM Fire Weather Program	35	34	-2.9	0.4
Transportation(Subtotal)	805	851	5.7	9.7
FHWA	0	0	0	0
FAA	805	851	5.7	9.7
EPA	0	0	0	0
NASA	37	29	-21.6	0.3
NRC	2	5	150.0	0.1
DOE	0	0	0	0
TOTAL	8808	8808	0.0	100.0

* Refer to Section 2, Resource Information and Agency Program Updates, Department of Defense, U.S. Army for details

Table 7 Interagency Fund Transfers

Summarizes the reimbursement of funds from one agency to another during FY 2011. 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 7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

		FY 2011 Funds ($K) Estimated or Planned		
Agency Funds Transferred from:	Agency Funds Transferred to:	Operations	Supporting Research	
USDA/USFS	DOI/BLM	717		
Air Force	NOAA			
Air Force Weather	DOC/NOAA/NWS	1648	120	NEXRAD
Air Force Weather	DOC/NOAA/NWS	50	150	ASOS
Air Force Weather	OFCM	153		OFCM cost share
Air Force Weather	OFCM	34		Aircraft data
Air Force Weather	USGS (Dept of Interior)	536		Magnetometer
Air Force Weather	NASA		550	Land Info Sys
Air Force Weather	NASA	373		JPL tech data
Air Force Weather	NSF/UCAR/NCAR		2101	WRF
Air Force Weather	NSF/UCAR/NCAR		1172	Data assimilation
Air Force Weather	NSF/UCAR/NCAR	250		Ensembles
Air Force Weather	NSF	800		GONG
Air Force Weather	GSA	25		Data admin
Air Force Weather	NOAA	98		DAPE program
Corps of Engineers	National Weather Service	320	224	
Corps of Engineers	US Geological Survey	18996		
TRADOC	Air Combat Command			
FAA(Contract Weather)	NWS APAIDS in Alaska	128		
FAA(Contract Weather)	NWS Cascade Locks	13		
FAA(Contract Weather)	NWS Meteorologists	376		
FAA(NEXRAD)	NWS	2500		
FAA(ASOS)	NWS	12479		
NASA	DOD/USAF/45th Space Wing	1780		
	DOD/USAF/Edwards AFB	110		
	DOC/NOAA/NDBC	103		
	DOC/NOAA/SMG	1700		
DOI/BLM SWA	USDA-NIFA	65		
DOI/BLM SWA	USDA-NRCS	50		
DOI/BLM OFA	USFS	835		
DOI/BLM OFA	DOD	341		

Table 8 Facilities/Locations for Taking Meteorological Observations

This table 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.

TABLE 8 Facilities/Locations Taking Meteorological Observations

TYPE OF OBSERVATION by AGENCY		No. of 2011 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)		92
Transportation (FAA Contract Wx Obsg Stn)*		147
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)		2253
Homeland Security (USCG Coastal)		50
Interior (BLM Soil/Water/Air Program)		200
Interior (BLM Office of Fire and Aviation)		971
Agriculture		1025
Agriculture (NRCS active manual snow courses)		1200
Agriculture (NRCS automated SNOTEL stations)		800
NASA (all types)		0
	Total	8720
*Note: All 147 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)		
Surface, marine		
Commerce (SEAS-equipped ships)		622
Commerce (Coastal-Marine Autom Network)		56
Commerce (NOS/PORTS - only stations with met sensors)		66
Commerce (Buoys--moored)		98
Commerce (Buoys--drifting)		21
Commerce (NOS/NWLON - only stations with met sensors)		181
Navy (Ships with met personnel)		29
Navy (Ships without met personnel)		255
Homeland Security (USCG Cutters)		248
NASA (Buoys - moored)		0
	Total	1576
Upper air, balloon		
Commerce (U.S.)		102
Commerce (Foreign, Cooperative)		22
Air Force, Mobile		29
Army, Fixed (U.S. & Overseas)		0
Army, Mobile (U.S. and Overseas)		0
Navy, Fixed (U.S. & Overseas)		0

Navy, Mobile(U.S. & Overseas)		10
Navy, Ships		29
Marine Corps, Mobile		10
NASA (U.S. and Overseas)		13
	Total	215
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		7
NASA (50 MHz)		1
	Total	26
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		0
Navy (Fixed)		9
	Sub-total	20
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)		0
Transportation (FAA (WSP))		34
	Sub-total	71
		295
Off-site WSR-88D Principle User Processors (PUPs)		
Air Force (OPUPs only)		99
Marine Corps (U.S. & Overseas)		9
Army		0
	Total	108
Weather reconnaissance Aircraft		
Commerce (OMAO)		3
Air Force Reserve Command (AFRC) - WC-130J		0
	Total	3
Geostationary meteorological satellites (No. operating)		
Commerce (2 primary, 1 standby, 1 servicing South America)		4
Polar meteorological satellites (No. operating)		
Commerce (2 primary - one US; one European, 3 standby)		5
Air Force (2 primary, 3 standby)		5

Navy (WINDSAT and GFO)		1
	Total	11
Electric Field Mills (Surface)		
NASA (KSC)		0
Army		3
	Total	0
Lightning Detection Systems		
Air Force (ER&WR - Cloud - Ground)		2
Air Force (ER&WR - NLDN)		2
Army		6
	Total	10

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.

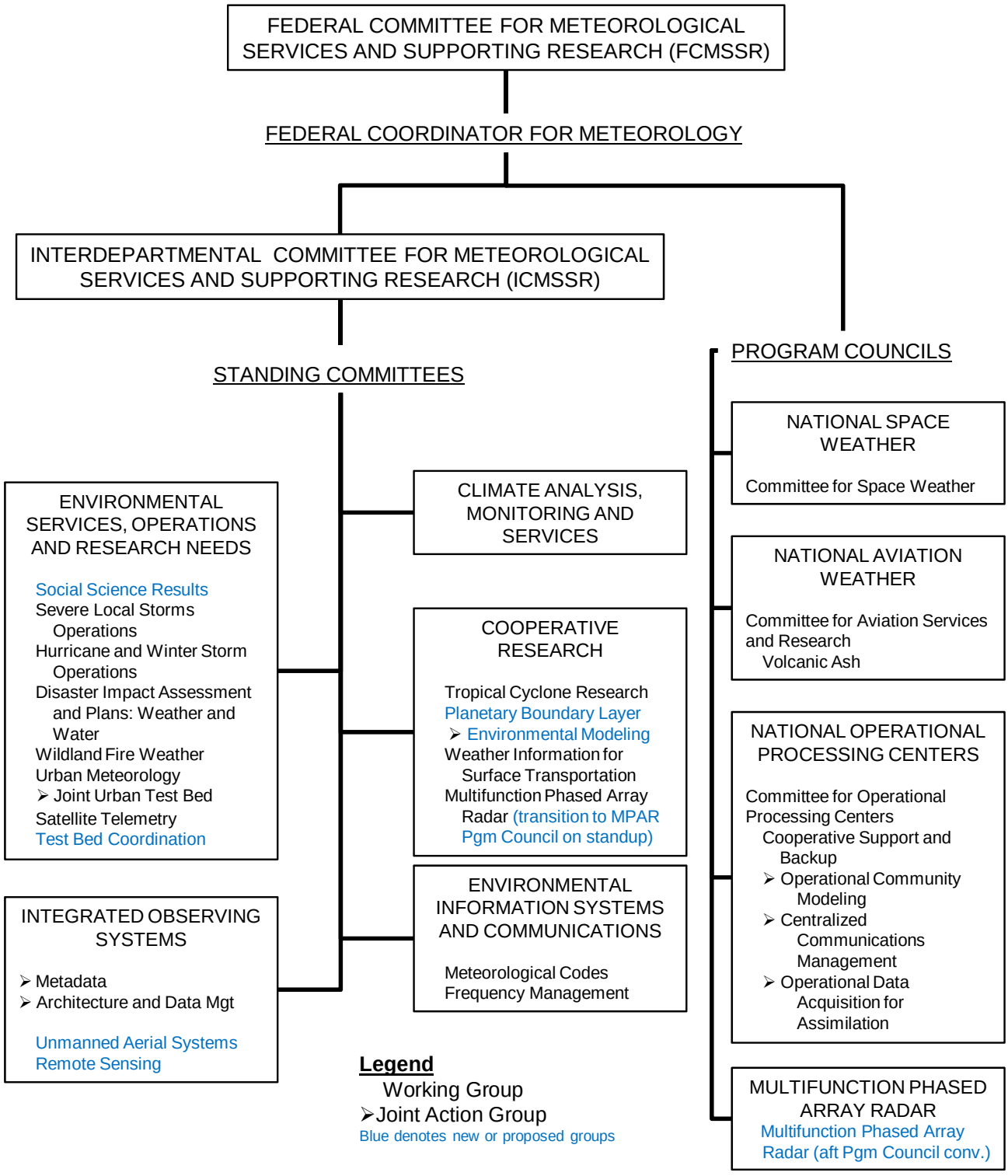
The FCMSSR comprises representatives of the 15 Federal agencies that engage in meteorological activities or supporting research, have a major need for meteorological services, or set policy and direction for such services and research. These 15 agencies are the Departments of Agriculture, Commerce, Defense, 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 2011 AND PLANS FOR FISCAL YEAR 2012

Federal coordination activities during FY 2011 and plans for FY 2012 are discussed here under the Program Council or ICMSSR standing committee that provided oversight of the associated working group or joint action group.

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 2012, 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.

During FY 2012, the Committee for Aviation Services and Research (CASR) will develop a NextGen Weather Research Roadmap. The initial focus of the effort is on meeting 4D Weather Cube content requirements for NextGen Mid-term Operational Capability (MOC) in 2018. The initiative will leverage NOAA National Weather Service (NWS) work that was already underway when CASR began this initiative.

In response to the volcanic ash airspace closure in Europe during 2010, the Working Group on Volcanic Ash (WG/VA), which is aligned under the CASR, coordinated interagency and international assistance to Europe and also worked with the NOAA National Weather Service on actions to improve U.S. preparations for a similar event. The WG/VA has developed a clear action plan to focus research for improved volcanic ash products and services, primarily for aviation, but exportable to all applications. Also, in June 2011, the WG/VA published the *National Volcanic Ash Operations Plan for Aviation and Support of the ICAO International Airways Volcano Watch: Pacific Northwest Regional Plan.*

National Operational Processing Centers Program Council (NOPC)

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 established satellite data management and exchange processes among the five operational processing centers to optimize the Federal investment in environmental satellite data acquisition.

In FY 2011, the OFCM continued 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 a 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 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 2012, 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.

National Space Weather Program Council

Based on a request in August 2008 to the National Space Weather Program (NSWP) 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 gave 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.

In June 2011, 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 2011 SWEF brought together more than 200 experts and stakeholders from government, science, and industry, including international participants. Media coverage and outreach raised awareness of space weather and its effects—the first step in creating a more resilient society and economy.

In the spring of 2011, the US and Great Britain agreed to work together to improve environmental prediction, including space weather services. The NSWP Council responded by initiating a high-level memorandum of understanding (MOU) among the Federal agencies engaged in space weather activities to establish the Unified National Space Weather Capability (UNSWC). The UNSWC will serve as the internationally recognized entry point to US space weather support and services, encompassing the ongoing contributions of the NSWP member agencies.

Also in 2011, the NSWP completed another report on space weather issues to OSTP to help inform the President's budget and respond to congressional interest. The report was entitled, "Space Weather Observing Systems: Current Capabilities and Requirements for the Next Decade."

As solar activities ramp up to an expected maximum in 2013, impacts from space weather on the national critical technological infrastructure are on the rise. Particular attention is being paid to the vulnerability of the national electrical power grid to disruption from geomagnetic storms.

Executive Council for Multifunction Phased Array Radar (MPAR)

The MPAR initiative seeks to consolidate the radar surveillance missions of four agencies (Department of Defense [DOD], Department of Homeland Security [DHS], DOC/NOAA, and the Federal Aviation Administration [FAA] in the Department of Transportation [DOT]), reducing the number of radars required and consolidating operations and logistics. MPAR risk reduction targets: (1) significantly reducing the cost of phased array technology, (2) validating the capability for one radar design to simultaneously meet the needs of four agencies, and (3) successful implementation of dual polarization on a phased array system.

MPAR risk reduction has been driven by *Federal Research and Development Needs and Priorities for Phased Array Radar* published by OFCM in 2006. This report included a Research and Development Plan, siting study, and early cost estimates.

The National Weather Radar Testbed (NWRT, the SPY-1 phased array radar at NOAA's National Severe Storm Laboratory) has demonstrated promising results for weather:

- Rapid updates identify severe weather signatures sooner; increase forecaster confidence.
- Adaptive scanning eliminates unnecessary, time-consuming surveillance of empty space.

There is still more to learn from the NWRT, but there are also serious limitations in that radar's legacy passive array technology. Meaningful upgrades would involve essentially replacing the radar. The MPAR Executive Council has considered and recommended work on two other options: the EQ-36 transportable radar project and the FAA/NOAA technology collaboration.

In June 2011, OFCM published a new Unified R&D Plan in June 2011. The plan organizes over 70 research elements under two major components: Technology Development and Test, and Proof of Operational Concepts. The plan also includes timeframe, priority, and technical and programmatic risk factors for each element.

The Technology Development and Test is the focus of current work of the NextGen Surveillance and Weather Radar Capability (NSWRC) program, an FAA program that is accomplished in collaboration with NOAA. The NSWRC establishes the timelines that drive the MPAR effort: a final investment decision in 2017 along with the operational deployment that would begin in 2023.

The Proof of Operational Concepts is the focus of the EQ-36 project, which proposes to develop a transportable dual polarization radar. This initiative includes the modification of a pre-production version of Army counter-fire radar for dual polarization. The 3-year project includes time share with the Army to investigate munitions ID.

The major outcomes of a meeting that took place on November 7, 2011, where most principal agencies comprising the OFCM-sponsored Executive Council for MPAR, were: (1) investigating a least cost option and compare with the EQ-36 option; and (2) clarifying requirements for wind turbine clutter mitigation and munitions ID.

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 2011 National Hurricane Operations Plan, which was published ahead of schedule on April 21. The updated plan was therefore ready well in advance of the 2011 hurricane season, enabling agencies to prepare for a potentially active season.

During 2011, the Working Group on Tropical Cyclone Research focused on assessing its 2010 snapshot of interagency R&D activities. The working group also participated 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 65th IHC was held in Miami, Florida, from February 28-March 3, 2011. The theme was *Ocean and Atmospheric Influences on Tropical Cyclone Predictions: Challenges and Recent Progress*. For the 12th consecutive year, about 200 personnel attended, including representatives from eight Federal agencies: DOC/NOAA, DOD (Navy, Air Force, Army Corps of Engineers), NASA, NSF, DHS (Headquarters Science and Technology, Federal Emergency Management Agency [FEMA]), FAA, Department of the Interior, and Department of Agriculture. Attendees also included representatives from academia, industry, and the emergency management community. All conference objectives were achieved, The 65th 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.

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 2011 and continuing in FY 2012, 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 (CAP). Under the five-year Umbrella Agreement and a FY 2011 funding agreement between the OFCM and the U.S. Air Force for up to $21,000 in reimbursable support, the CAP flew nine missions: four missions in support of glacial lake damming assessments in Alaska; two missions in support of tornado damage assessments in North Carolina, Mississippi and Alabama; two missions in support of severe flooding in Kentucky, Illinois, Missouri, Nebraska and Arkansas; and one mission in support of catastrophic flooding in Vermont associated with the remnants of Hurricane Irene. The CAP support for aerial data acquisition surveys will continue in FY 2012 at a planned level of $21,000. During FY 2012, the OFCM will work with the Air Force to develop a new umbrella agreement for CAP support for FY 2012-2016.

In the days leading up to and after landfall of Hurricane Irene, there was great response and coordination across the membership of the WG/DIAP. During Irene at least four groups deployed mobile sensors and instrumentation for collecting wind speed data. There were numerous federal and academic teams that also deployed mobile instruments to collect storm surge and other water level and wave data. As outlined in the national plan, the WG/DIAP is compiling a list of web sites for weather and water data collected during Irene.

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 developed 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, culminated in May 2011 with the publishing of the report, *Wildland Fire Weather: Multi-Agency Portfolio of Current and In-development Capabilities.*

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 2011, 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 2012, 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 12-14, 2011, the OFCM cosponsored the 15th Annual George Mason University Conference on ATD Modeling. The themes of the conference were: (1) improve understanding of atmospheric transport and dispersion processes; (2) support homeland security requirements; and (3) share experience across different sectors. In a panel session organized by the OFCM, the panel moderator and four panel members gave presentations, from both scientific and operational perspectives, regarding ongoing work and progress in implementing the recommendations in the OFCM report, *Federal Research and Development Needs and Priorities for Atmospheric Transport and Diffusion Modeling*.

Working Group for Test Bed Coordination (WG/TBC)

Among CESORN plans for FY 2012 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.

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 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 2012 includes 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 took place in February 2011, when OFCM conducted an *Exploratory Mini-workshop on the Utilization of UAS for Environmental Monitoring* on February 4, 2011. Some key points regarding the workshop are:

- Gathered 33 participants and 12 federal agencies to focus on UAS issues.
- Created connections to foster cooperation among agencies pursuing UASs for environmental monitoring, and published a Summary Report (FCM R32-2011).
- Impact: focused attention of the federal government on the potentially game-changing capabilities of UAS platforms to perform environmental monitoring.

The workshop complemented 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.

NOAA and NASA have an active partnership for developing and using UAS for weather and climate research campaigns for tropical cyclone, arctic, and other missions. The NOAA UAS

Program is working to determine how and when UAS platforms can begin to augment its fleet of manned aircraft for both operational and research missions. NASA's Hurricane and Severe Storm Sentinel (HS3) experiment relies heavily on UASs.

In FY 2011, there was growing Pacific Air Forces (PACAF) and NOAA interest to apply the knowledge, expertise, and success of NASA's Global Hawk UAS tropical cyclone experiments in the Atlantic Ocean to the Pacific Basin. The initial goal is a Joint DoD/NASA/NOAA experiment during a NW Pacific tropical cyclone season to illustrate Global Hawk capability and operational benefits.

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 2011, 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 2012 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 R&) activities supporting the surface transportation community, building on its December 2002 publication, *Weather Information for Surface Transportation--National Needs Assessment Report.* During FY 2011, 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 2012 include (1) integrating planetary boundary layer activities and advances to improve road weather capability; (2) coordinating with CIOS on observing systems and activities; (3) balancing road/highway observation system efforts with additional focus on products and services for transportation system managers and users; and (4) begin to develop a WIST R&D strategy.

Planetary Boundary Layer

A new focus area for the Committee on Cooperative Research during FY 2012 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 2012 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 2012, 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 2011 activities for this working group, which will continue in FY 2012, 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 2012.

Committee on Environment, Natural Resources, and Sustainability (CENRS)

CENRS Principals. The Federal Coordinator served as a member of CENRS, a committee of the National Science and Technology Council, during FY 2011 and will continue to serve in FY 2012.

Subcommittee on Disaster Reduction. The OFCM has been an active participant in the work of the CENRS 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.

American Meteorological Society

The OFCM supports AMS activities by participating in AMS conferences and workshops and other environmental science education and outreach programs. In FY 2011, the OFCM presented two papers at the 91th AMS Annual Meeting 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 2011 included the 65th IHC and the 2011 Space Weather Enterprise Forum. Plans for international collaboration during FY 2012 include the 66th IHC and the 2012 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 2011 OFCM PUBLICATIONS

The publications listed in the table below were prepared in hard copy and/or were added to OFCM's web site (www.ofcm.gov) during FY 2011.

OFCM PUBLICATION	DATE	NUMBER
PLANS		
National Severe Local Storms Operations Plan	November 2010	FCM-P11-2010
National Hurricane Operations Plan	May 2011	FCM-P12-2011
National Winter Storms Operations Plan	November 2010	FCM-P13-2010
Multifunction Phased Array Radar Unified Research and Development Plan	June 2011	FCM-P36-2011
National Plan for Disaster Impact Assessments: Weather and Water Data	November 2010	FCM-P33-2010
National Volcanic Ash Operations Plan for Aviation and Support of the ICAO International Airways Volcano Watch: Pacific Northwest Regional Plan	June 2011	FCM-P35-2007
REPORTS		
Utilization of Unmanned Aircraft Systems for Environmental Monitoring Exploratory Mini-Workshop Summary Report	May 2011	FCM-R32-2011
Wildland Fire Weather: Multi-Agency Portfolio of Current and In-development Capabilities to Support User Needs	May 2011	FCM-R34-2011
HANDBOOKS		
Federal Meteorological Handbook No. 3 - Rawinsonde and Pibal Observations, Part A: System Concepts, Responsibilities, and Procedures	March 2011	FCM-H11A-2011

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

National Weather Service

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 extreme temperatures.

The NWS uses surveillance and data collection technologies such as a national network of Doppler weather radars, satellites operated by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), data buoys for marine observations and tsunami detection, surface observing systems for the safe operation of airports, and weather balloons to obtain vertical measurements of the atmosphere. Some observations are obtained through the Cooperative Observer Program, which is a nationwide network of volunteer-operated weather observing sites. Many other observations are contributed through arrangements with publicly and privately operated networks. Observations feed sophisticated environmental prediction models running on high-speed supercomputers, which provide weather, water, and climate forecast guidance that are available to all users. 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, satellite broadcast, and the Internet.

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 the 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 in effective public response and improvements to NWS services.

The Advanced Weather Interactive Processing System (AWIPS) is a technologically advanced information processing, display, and telecommunications system that is the cornerstone of the National Weather Service (NWS) modernization and restructuring. AWIPS is an interactive computer system that integrates all meteorological and hydrological data, and all satellite and radar data, for the first time, and enables the forecaster to prepare and issue more accurate and timely forecasts and warnings (NOAA Image)

NCEP consists of nine national centers that provide a backbone of national expertise for both forecast capabilities and numerical guidance. The NCEP Storm Prediction Center (SPC) provides forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. The SPC also monitors heavy rain, heavy snow, and provides national outlooks on fire weather potential. The National Hurricane Center (NHC) monitors the tropical North Atlantic, Caribbean and Gulf of Mexico for the development and prediction of tropical cyclones and provides educational outreach and guidance for the international community in the region. While not part of NCEP, the Central Pacific Hurricane Center (Honolulu) and the Joint Typhoon Warning Center (Guam) provide additional tropical cyclone coverage for the central and western Pacific. The Hydrometeorological Prediction Center (HPC) provides analyses and forecast guidance on general weather patterns with a focus on precipitation type and amount and winter precipitation. The Ocean Prediction Center (OPC), along with a component of NHC, issues marine forecasts for the Atlantic and Pacific oceans. The Aviation Weather Center (AWC) provides aviation warnings and forecasts of hazardous flight conditions at all levels within domestic and international air space. The Climate Prediction Center (CPC) monitors and forecasts short-term climate fluctuations and provides information on the effects that climate patterns can have on the Nation. The Space Weather Prediction Center (SWPC) provides space weather alerts and warnings for disturbances that can affect people and equipment working in space and on Earth. The Environmental Modeling Center (EMC) and NCEP Central Operations develop, maintain, and execute a suite of numerical analysis and forecast models.

There are other specialized service centers within the NWS, such as the Pacific Tsunami Warning Center (PTWC) and the West Coast/Alaska Tsunami Warning Center (WC/ATWC), which use data from deep water buoys located throughout the Pacific Ocean, Atlantic Ocean, and Caribbean Sea to issue tsunami watches and warnings for all U.S. and many international communities. The National Data Buoy Center (NDBC) is responsible for the deployment and maintenance of coastal and ocean buoys and sensors that are used for marine forecasts and

analysis of ocean-based storms . The NWS Volcanic Ash Advisory Center (VAAC) located in Anchorage, Alaska, provides worldwide warnings and advisories to aviation interests regarding airborne volcanic ash hazards (see further description of the global system of VAACs in the section on volcanic ash in Aviation Services.)

NWS forecasters support several health-related programs such as Air Quality, Heat Health, and the Ultraviolet Index. The NWS Air Quality Forecast Services prepare 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 U.S. 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. Also, in partnership with the EPA, a climatologically based ultraviolet alert is being produced for the entire Nation.

NOAA/NESDIS

NOAA's 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 circle the Earth in a nearly north-south orbit, passing close to both poles. These satellites ensure observational 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 the National Aeronautics and Space Administration (NASA).

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

The President's FY 2011 budget contained a major restructuring of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program to put this critical POES program on a more sustainable pathway toward success. The POES system is a National priority: essential to meeting both civil and military weather-forecasting, storm-tracking, and climate-monitoring requirements. At the time of restructuring, the NPOESS program was behind schedule, over budget, and underperforming. Independent reports and an administration task force concluded that the program could not be successfully executed with the existing management and budget structure. NOAA and the U.S. Air Force (USAF) have nearly completed the transition from NPOESS to its successor, the Joint Polar Satellite System (JPSS). NASA is serving as NOAA's acquisition agent for the JPSS program. Whereas the USAF has several remaining DMSP polar-orbiting satellites available for launch over 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. Maintaining launch progress for the NPOESS Preparatory Project (NPP), intended as a prototype of next-generation POES, is the highest priority for JPSS. NOAA/NASA oversight of the ground system has enabled NPP to remain on track for an October 2011 launch. In addition, these agencies have a strong partnership with Europe through EUMETSAT, which will continue to be a cornerstone of a joint polar-orbiting constellation and will ensure NOAA/NESDIS's ability to provide continuous measurements. These changes to the POES program will 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. The GOES system provides continuous observations of environmental conditions of North, Central, and South America and the surrounding oceans. These spacecraft provide data critical for fast, accurate weather forecasts and warnings, detection of solar storm activity, and relay of distress signals from emergency beacons. They provide nearly continuous monitoring necessary for effective, detailed, and extensive weather forecasting, prediction, and environmental monitoring

There are two operational geostationary satellites for the North American region, 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 coverage for South America.

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 is called the Geostationary Operational Environment Satellite–R Series (GOES-R). The advanced spacecraft and instrument technology used on the GOES-R series will result in more timely and accurate weather forecasts. It will improve support for the detection and observations of meteorological phenomena and directly benefit public safety, protection of property, and ultimately, economic health and development. GOES-R will scan its field of view on the Earth nearly five times faster, with more than three times the spectral coverage and four times the spatial resolution of 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 2012, the GOES-R program plans to continue instrument and spacecraft development to meet phased instrument delivery milestones beginning in 2012. Both the Spacecraft Critical Design Review and the Ground Systems Critical Design Review are planned to meet the scheduled 2015 launch date.

NOAA/NESDIS Data Centers

National Climatic Data Center

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

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 than 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 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 that influences 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 (NGDC-720). The NGDC-720 model corresponds to a 15-arc-minute model resolution.

National Oceanographic Data Center

The National Oceanographic Data Center (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 Office of Marine and Aviation Operations

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 (1) aircraft that collect environmental and geographic data essential to NOAA hurricane and other severe weather and atmospheric research and (2) 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 NDBC in recovery of buoys that have been disabled or gone adrift.

NOAA supports 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 twelve 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 track forecasts and for research leading to improvements in hurricane intensity forecasts.

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)–equipped dropsondes at preselected locations. The data from these vertical atmospheric soundings are received, processed, and transmitted from the aircraft to a NOAA NCEP computer site, where they are incorporated into computer models of hurricanes to improve hurricane track forecasts. Each dropsonde directly measure temperature, pressure, and humidity at the rate of two samples per second as it falls through the atmosphere to the surface and computes wind speed and wind direction at a rate of four samples per second, using a full-up GPS receiver. Recent estimates of the improvement in hurricane track predictions utilizing this technology show an improvement of between 20 and 30 percent, which represents a savings of $10 million or more per hurricane in warning and preparedness costs.

The G-IV is also used for winter storm surveillance in the Pacific, operating from bases in Japan, Hawaii, and Alaska. Flights are in support of NCEP's ongoing program to improve winter storm forecasts in the United States.

Two NOAA WP-3D Lockheed Orion aircraft (N42RF and N43RF) support NOAA's atmospheric and oceanographic research, as well as its tropical storm and hurricane reconnaissance operations. The aircraft's 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, installs and integrates user-supplied instrumentation into the aircraft and data network, and processes data for immediate satellite transmission or future analysis. The NOAA WP-3D aircraft, while executing the complex flight patterns required for hurricane research, also provide storm data to the NHC in real time, transmitting flight level data and GPS dropsonde messages,

as well as radar images transmitted via their 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.

During each hurricane season, the two NOAA WP-3Ds support several major research experiments in support of NOAA's Hurricane Research Division (HRD) of NOAA's Atlantic Oceanographic and Meteorological Laboratories in its Intensity Forecast Experiment (IFEX), an ongoing program studying hurricane genesis, rapid intensification, and other related experiments. A relatively new and exciting part of this research effort is the collaboration with NOAA's EMC in a program to obtain three-dimensional horizontal wind fields in developing tropical systems and hurricanes, utilizing the Tail Doppler Radars of the WP-3D aircraft. The objective of this effort is to obtain data that can be assimilated into the Hurricane Weather Research and Forecasting (HWRF) model for the purpose of improving hurricane intensity forecasts. Extensive descriptions of the various hurricane research experiments may be found in the HRD Field Program Plan for 2011.

The NOAA WP-3D aircraft annually participate in both summer and winter operations supporting the NESDIS satellite validation program. Operating in regions of high winds and heavy precipitation, one of the WP-3Ds, equipped with microwave scatterometers and radiometers, provides under-flight validation of the ocean surface wind vectors sensed by the European ASCAT and Indian OceanWind2 satellites. Traditional venues for these satellite validation operations are Alaska or Newfoundland in the winter and the Atlantic and Caribbean regions during the summer hurricane season.

These versatile aircraft also routinely support NOAA's air quality research programs. Most recently the N43RF aircraft has supported the Chemical Science Division of The Earth System Research Laboratory (ESRL) in a major air quality study of the Los Angeles basin and the San Joaquin Valley in California as part of a joint venture, known as CalNex, of the California Air Resources Board, NASA, the U.S. Department of Energy (DOE), and the Office of Naval Research (ONR). For this project, a WP-3D is converted to a flying air chemistry laboratory for the sampling of atmospheric gases, particulate matter, and radiative fluxes. While equipped this way, the aircraft also flew several survey patterns over the oil spill from the Deep Horizon oil well disaster. The results of these surveys show that aircraft so equipped can make a major contribution to monitoring major oil spills in the oceans.

NASA Basic Meteorological Services

NASA is a long-term partner with NOAA for building and launching U.S. POES and GOES civilian weather satellites under reimbursable arrangements. For example, NOAA will fund the JPSS Program, with NASA serving as the acquisition agency. NASA is also collaborating with NOAA to acquire key climate measurements and transition them into the operational system.

NASA coordinates with the US Geological Survey (USGS) on the Landsat Data Continuity Mission (LDCM) (also called Landsat 8). Future Landsat missions will be funded through the USGS, with NASA serving as the acquisition agency.

NASA consistently supports and develops programs to improve public understanding of the complexity of the global integrated Earth system and to educate and train the next generation of scientists and engineers. NASA is the largest contributor to the Global Learning and Observations to Benefit the Environment (GLOBE) Program. NASA supports innovative projects in formal and informal education to stimulate Science, Technology, Engineering, and Mathematics (STEM) learning in schools, such as the DEVELOP (not an acronym) Program, and to engage the public. NASA's Earth System Science Fellowship Program trains graduate students.

Federal Aviation Administration Contributions to Basic Services

Automated Surface Observing System (ASOS). ASOS, a joint program of the Federal Aviation Administration (FAA), NOAA/NWS, and the Department of Defense. The ASOS units installed at 884 sites serve as the nation's primary surface weather observing network. ASOS is designed to support routine weather forecast activities and aviation operations while also supporting the needs of the meteorological, hydrological, and climatological research communities for basic, in situ observations. About 426 ASOS units are installed at towered airports where the FAA provides augmentation/backup of the observations. The remaining ASOS units are installed at non-towered airports where its automated observations support FAA Service Level D weather reporting capabilities. (FAA aviation weather Service Levels are discussed in the section on Aviation Services.) ASOS units work nonstop, updating observations every minute, 24 hours a day, every day of the year.

At airports that do not have an ASOS unit, the FAA's Automated Weather Observing System (AWOS) provides basic aviation weather observations directly to pilots approaching the airport. The AWOS Data Acquisition System (ADAS) functions as a message concentrator for observations from ASOS, AWOS, and the FAA's Automated Weather Sensor Systems. These capabilities, which serve the aviation community, are described further in the Aviation Services section.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

Interagency Research Programs

The United States Weather Research Program (USWRP)

The USWRP is an interagency program for weather research and the transition of research to applications. The member agencies include NOAA (lead), NASA, the National Science Foundation (NSF), the Navy, and the Air Force. The NOAA component of the USWRP has been quite active although the funding levels have been flat. NOAA's Office of Oceanic and Atmospheric Research (OAR), through its Office of Weather and Air Quality, helps plan NOAA USWRP priorities, implements the program, and monitors progress. In FY 2011 and FY 2012, the USWRP funded the following projects:

The Developmental Test Center (DTC). The DTC (http://www.dtcenter.org/index.php) is a joint operation between NOAA/ESRL/Global Systems Division (GSD) and the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, Funded by NOAA, the DTC 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 2012, the DTC will continue to develop the HWRF community hurricane 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 2012. Its mission is to be a clearing house for socioeconomic information on weather, to increase knowledge within 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 2012, the SIP will continue work to determine how the public understands forecast uncertainty and to research the communication, use, and value of hydrometeorological information, undertaking outreach and education.

The Joint Hurricane Testbed (JHT). The NOAA USWRP provides support for the JHT, 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 NCEP's Tropical Prediction Center in Miami, Florida. The USWRP will continue to support the JHT in FY 2012. Recently, the JHT has been emphasizing improving forecasts of hurricane intensity at landfall. In FY 2012, the JHT will be at the beginning of its sixth cycle of two-year awards. This cycle has 13 awards.

The Hydrometeorological Testbed (HMT). The 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 the Physical Sciences Division (PSD) of NOAA/OAR/ESRL. The HMT seeks to improve regional precipitation forecasts, particularly for heavy, flooding rains. This support will continue as the HMT moves from the west coast to set up a field program in the southeast United State. This project also collaborates with OAR's National Severe Storms Laboratory (NSSL).

The Observing System Simulation Experiment (OSSE) Testbed. The NOAA USWRP provides support for the OSSE Testbed. The OSSE aims to establish a numerical test bed that will enable a hierarchy of experiments to determine the potential impact of proposed space-based, sub-orbital, and in situ observing systems on analyses and foecasts, evaluate trade-offs in observing system design, and assess proposed methodology. In FY12 the OSSE testbed will continue to provide expertise to NOAA, the Joint Center for Satellite Data Assimilation (JCSDA) partners, and academia.

Joint Center for Satellite Data Assimilation

Effective environmental prediction requires several elements. One of these is a global observing system that provides accurate, well-distributed measurements of the Earth's environment. Another element consists of the numerical models that effectively 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. The 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 United States. The 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 JCSDA has the following goals:

- Reduce the average time for operational implementation of data from new satellite sensors to one year.
- Increase the use and impact 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.

By meeting these goals, the JCSDA achieves its objective of maximizing the nation's return on its investment in observing systems and modeling by providing improved support for U.S. military actions and improving the guidance used by forecasters to protect citizens' lives and property.

Wind Forecast Improvement Project (NOAA–DOE Collaborative Project)

The Wind Forecast Improvement Project (WFIP) is a collaboration of NOAA, DOE, two private wind energy companies, and academic research institutions. The goal is to lower the cost to utilities of wind-derived electric power by improving the foundational wind forecast for all users, including wind power and utility system operators.

DOE contributes funding for WFIP and scientific expertise from within its national research laboratories, while NOAA contributes scientific expertise in collecting atmospheric data and in making weather models and forecasts. The project targets the Upper Midwest and West Texas, which were selected in part because WFIP industry partners operate thousands of wind turbines in these areas. WFIP researchers will capture detailed data on wind speed and direction in the atmosphere up to 400 feet above the ground, using instruments such as wind profiling radars, sodars, and anemometers located at normal reading heights and on meteorological tall towers.

Turbines near the Dyess Air Force Base in Texas generate power for the base. Photo courtesy of the National Renewable Energy Laboratory.

The data will be used as additional input to a high-resolution research weather model at OAR/ESRL. Scientists expect the additional observations will improve the accuracy of regional weather forecasts for the lower atmosphere–thus affecting the wind industry forecasts at turbine level. WFIP researchers will evaluate the value of various types of weather data for improving the accuracy of weather

forecasts, as well as the economic value of improved forecasts to the wind utilities. The WFIP is the first of a growing number of joint agency efforts under a Memorandum of Understanding on "Weather-dependent and Oceanic Renewable Energy Resources" signed by NOAA and DOE in January 2011. The agreement set up a framework for NOAA and DOE to work together on renewable energy modeling and forecasting.

NOAA/NWS Research Programs and Projects

Continually improving the accuracy, timeliness, and accessibility to prediction services is largely a result of research and development (R&D) within the NWS, at other NOAA offices such as OAR, and externally from universities and private corporations. NCEP/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. 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 JCSDA, which is 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 develops 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 communities. EMC also participates in ongoing interactive research programs such as NOAA's Hurricane Forecast Improvement Project (HFIP) and the WRF community 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 modeling approach has been applied operationally at short, medium, and extended ranges. EMC efforts in collaborative development resulted in improvements to mesoscale and global models, as well as advances 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 works to create products that monitor atmospheric, oceanic, and environmental hazards; enhance NOAA's infrastructure for remote sensing; reduce the risks associated with launching new, untested, and very expensive satellites and sensors; and expand its support to satellite data users.

Satellite Research Projects

Hurricane Applications of Lightning Measurements. The next-generation NOAA geostationary satellites, starting with 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. In addition, location and frequency of lightning discharges are useful indicators of storm development and intensity. 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 2012 will continue to focus on ways to use a new ground-based lightning network, which can provide some information on 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 with 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 are 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 predictions of rapid storm intensity change, which is an especially challenging forecast problem. Ongoing research will generalize this study to tropical cyclones in ocean basins other than the Atlantic Basin and will develop experimental forecast algorithms for rapid intensification, using 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 inhabited land will help to improve the reliability of hurricane watches and warnings, which are important for evacuations and other mitigation activities.

Precipitation Estimation Using Satellite Observations. 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. Data from GEOS instruments sensing in the infrared and visible regions of the electromagnetic spectrum provide high-resolution, rapidly updated rainfall information for hazardous-weather applications. More-accurate estimates of rainfall can be derived from microwave-frequency instruments onboard POES, but their less frequent updating makes them more suitable for longer term water monitoring. In FY 2011 and into FY 2012, NOAA will continue to develop the algorithms for the next generation of NOAA's GOES. In addition, modifications to the current generation of algorithms will be explored, in search of better ways to serve the users of these data

Microburst Assessment from Satellites. A suite of products derived from the current generation of GOES was developed and evaluated to assess hazards to aircraft in flight presented by convective storms and associated high winds. 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 (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 evaporative 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). It 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 2012 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/OAR Laboratories

Air Resources Laboratory (ARL)

ARL conducts R&D 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. ARL research contributions are also discussed in the Support Research section of Emergency Response and Homeland Security Services.

Earth System Research Laboratory

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 UASs for improved U.S. and global observing in areas too remote or dangerous for lengthy manned flights, e.g., the polar regions and hurricanes. High and medium altitude, long-endurance UASs (HALE and MALE-class) can fly at remote locations in dangerous flying conditions for long periods. This technology provides many scientific benefits such as sustained global high quality all-weather profiles of atmospheric composition (water vapor, 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/GSD is conducting global and regional

Observing System Simulation Experiments to evaluate the potential benefits of UAS sampling of hurricanes and their environment.

Scientists at GSD have developed GPS-Meteorology (GPS-Met), a ground-based research system that uses 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 United States. The data are distributed by GSD using an Internet 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/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.

Meteorological Assimilation Data Ingest System (MADIS). The demands for finer scale meteorological services have increasingly required higher resolution observations to initialize and evaluate weather and climate models, applications, and products. In response to these demands, ESRL/GSD developed MADIS to collect, integrate, quality control, and distribute observations from NOAA and non-NOAA organizations. MADIS leverages partnerships with international agencies; Federal, State, and local agencies (e.g., State departments of transportation); universities; volunteer networks; and the private sector (e.g. airlines, railroads) to integrate observations from their in situ observing networks with those of NOAA/NWS to provide a finer density, higher frequency observational database for use by the greater meteorological community. MADIS observational products and services were first provided to the public in July of 2001.

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 thunderstorms, tornadoes, flash floods, lightning, winter storms, and their associated impacts. 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 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. MPAR is a promising option for meeting the Nation's future domestic radar surveillance needs. Using multiple beams and frequencies that are controlled electronically, NSSL has demonstrated that phased array radar reduces the scan time 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.

In FY 2012, NSSL will continue collaborating with the Federal Aviation Administration (FAA) and industry in designing and testing dual-polarized phased array radar panels required to determine the feasibility of using MPAR as the replacement technology for weather and aircraft surveillance radars. 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 brought their warning decision making expertise to Norman, Oklahoma, to participate in the Phased Array Radar Innovative Sensing Experiment (PARISE). They continued to investigate whether faster data updates increases warning lead-time (as preliminary results have shown). NSSL continues to conduct 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 phased array radar technology. NSSL also continues to work on signal processing improvements including range oversampling, beam multiplexing, ground clutter canceling, and other techniques to improve the quality, usability, and availability of radar data. In addition to learning about the impact of temporal sampling on warning decision making, PARISE will continue to evaluate data processing and collection

techniques unique to NSSL's Phased Array Radar Program, such as electronic adaptive scanning and scheduled scanning that are adapted to end users' needs.

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 NSF. Nearly 100 scientists and students from 16 different universities and various other academic organizations in the United States took part in the experiment. VORTEX2 also involved forecasters from NWS WFOs, NCEP's Storm Prediction Center, Environment Canada, the Australia Bureau of Meteorology, and Finland. The VORTEX2 teams were seeking 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 total, data was collected on 41 supercell thunderstorms, with 10 tornadoes observed with the experimental instrumentation. These data are now being analyzed for selected cases and will be used to study tornado development, evolution, and their associated signatures.

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 technology (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; for example, 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 that increases lead time and provides probabilistic information that enables the public to take the most reasonable action during a severe weather event. The WoF program is being conducting in collaboration with ESRL/GSD; NCEP's Storm Prediction Center; NWS Norman, Oklahoma, WFO; and several academic partners. Data from VORTEX2 will be valuable in developing, testing, evaluating, and improving WoF computer models and techniques.

Storm-scale Hydrometeorology Research. The Coastal-Inland Flood Observation and Warning (CI-FLOW) project uses NSSL's multisensor rainfall estimates to drive an NWS distributed hydrologic model that predicts streamflow, which helps the 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 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 assessment studies.

Atlantic Oceanographic and Meteorological Laboratory (AOML)

Two major areas of AOML research are ocean-observing technologies and tropical cyclone research.

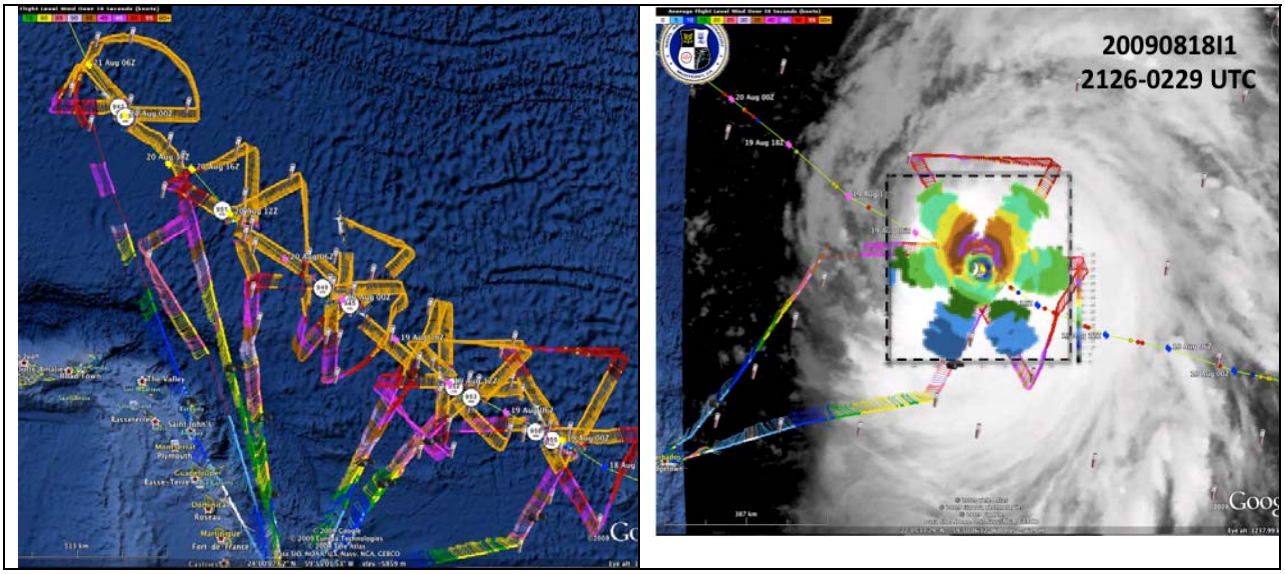
Ocean Observing Technologies. In addition to the many weather-related observing systems, OAR is dedicated to improving the development, deployment, and monitoring of oceanographic-related observing technologies and related data. As part of this effort, AOML manages the deployment of drifting buoys around the world, deploying some 900 new drifters annually and tracking approximately 1,250 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 a 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 (TSGs) 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 Microsoft 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 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 each 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 transmitted in real time into the GTS and are being used to initialize weather and climate forecast models.

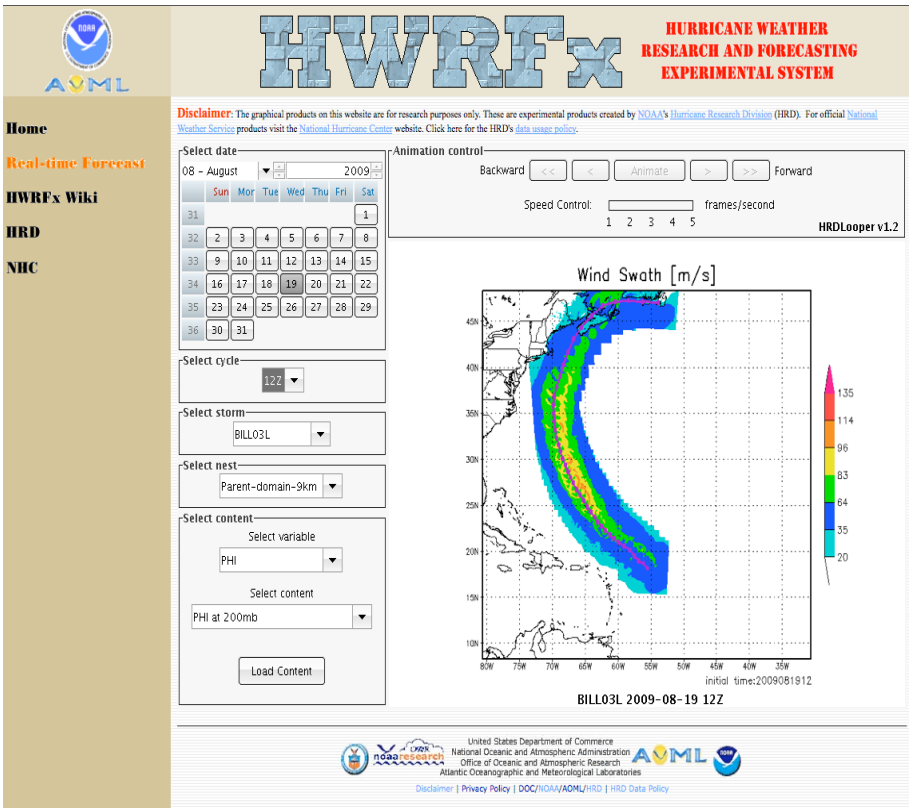
Tropical Cyclone Research. To improve tropical cyclone track and intensity forecast guidance, AOML's Hurricane Research Division (HRD) uses in situ and remotely sensed data collected by

aircraft, satellites, and buoys and computer model simulations of the inner core of tropical cyclones and their surrounding environment. An aircraft field program is used to gather datasets representing all stages of the storm's lifecycle; these datasets are used to both support operational needs and provide the cornerstone of HRD's research. The observations are primarily collected during the hurricane season using two NOAA turboprop aircraft and a Gulfstream-IV jet operated by NOAA's AOC. Because of their 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 with 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 HRD's hurricane research is based on analysis of in situ and remotely sensed observations of the core of tropical cyclones and their surrounding environment. These analyses are used to improve the general understanding of tropical cyclones and provide valuable information for the initialization and evaluation of next-generation numerical models. Observations are primarily collected as part of the NOAA Intensity Forecast Experiment (IFEX), a partnership involving HRD, TPC, EMC, and NESDIS. These observations are collected during hurricane season using the fleet of U.S. Air Force Reserve WC-130J aircraft, the two NOAA WP-3D turboprop aircraft, and the Gulfstream-IV jet operated by the AOC. The goal of IFEX is to collect observations that directly aid in the development and evaluation of HWRF, the next-generation tropical cyclone forecast modeling system, under the new NOAA Hurricane Forecast Improvement Project (HFIP).



Real-time maximum surface wind swath produced by the HWRFx model for Hurricane Bill on 0000 UTC 19 August 2008. The track is depicted in magentat with dots long the track every 3 h.

HRD also maintains active research programs with other governmental agencies and arranges cooperative programs with scientists at NCAR and numerous universities. For example, in August-September 2010, HRD collaborated with NASA and NSF–supported researchers, combining observing capabilities to sample a number of tropical cyclone to address tropical cyclogenesis and rapid intensity change, which are key problems for NOAA operational forecasters. NASA conducted the Genesis and Rapid Intensification Processes (GRIP) field campaign to learn why a tropical storm forms and strengthens into a hurricane. NASA provided innovative instruments to record detailed atmospheric measurements through a tropical storm or hurricane for 20 hours by NASA's Global Hawk UAS, flying above the disturbance, while additional observations were taken at different heights within the disturbance with NASA's DC-8 and WB-57 aircraft. The Pre-Depression Investigation of Cloud-systems in the Tropics (PREDICT) project, sponsored by NSF, focused on the pre-depression or genesis phases of tropical cyclones using NSF's G-V sampling of synoptic-scale disturbances with GPS dropsondes. By combining resources, the three agencies could provide diverse observations of a single storm simultaneously from as many as six airborne systems, all transmitting high-quality observations to support operational needs at NHC and EMC.

The HFIP is a unified 10-year NOAA plan to improve the 1-day to 5-day forecasts for tropical cyclone activity, with a focus on rapid intensity change. Researchers at HRD, together with 2-3 researchers at OAR's Geophysical Fluid Dynamics Laboratory (GFDL), 5-6 researchers at

ESRL, and 4-5 researchers at NCEP/EMC make up the NOAA core capability for hurricane R&D and play a major role in the HFIP. The HFIP is only feasible because of these core capabilities at HRD, AOML, GFDL, and ESRL. Within the NWS, NCEP/NHC, the Central Pacific Hurricane Center, and the hurricane-modeling group at NCEP/EMC comprise the NOAA core operational hurricane capability.

HRD's strengths in tropical cyclone research and longstanding collaboration with academia and other Federal agencies provide NOAA with a core capacity to address HFIP's goals, which are grounded in the operational needs of the NWS. 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 goals will require major investments in enhanced observational strategies, improved data assimilation, numerical model systems, and expanded forecast applications based on high resolution and ensemble-based numerical prediction systems. The *objectives* of the HFIP are to coordinate hurricane-related R&D within the NOAA entities mentioned above and to broaden their interactions with the outside research community in order to address NOAA's operational hurricane forecast needs. 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. These outcomes can 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 for HFIP include:

- Reduce average track error by 50 percent for [forecast] 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 the University of Miami's Rosenstiel School of Marine and Atmospheric Science, the University of Rhode Island, and the Naval Research Laboratory (NRL); (2) improved understanding of the role of aerosol and microphysical processes in collaboration with NCEP/EMC, NASA's Jet Propulsion Laboratory, NRL, the

University of Rhode Island, and University of Tel Aviv; and (3) improved understanding of land surface impacts on rainfall and flooding through collaboration with NCEP/EMC and Purdue University.

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. High resolution atmospheric modeling is the central tool in this work. Recent research using these models has exposed a potential breakthrough in predicting seasonal hurricane activity: atmospheric models forced with observed SST 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: (1) employing meteorological observations in conjunction with models for diagnostic analyses of atmospheric processes; (2) evaluating and improving parameterizations employed in weather and climate models; (3) modeling the interactions between clouds, convection, radiation and large-scale dynamics to understand their roles in climate and climate change; and (4) 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.

An understanding is being developed of the role of extreme events and abrupt change, their regional impacts, and their interactions with natural variability, so that decisions to prepare for and confront these effects can be made with the best possible scientific information. GFDL's Climate Change, Variability, and Prediction group leads a vigorous research program on decadal variability, predictability, and predictions. At the heart of that program are efforts to better understand physical processes that contribute to decadal variations and predictability in the climate system, particularly in terms of the role of the ocean as a driver of decadal-scale variations.

GFDL is conducting a very large set of decadal hindcast and prediction experiments, perhaps the largest set of any of the modeling centers around the world. These experiments are primarily using the GFDL CM2.1 climate model (atmospheric resolution of 200 Km, ocean resolution of 100 Km). Using initial conditions from GFDL's recently developed coupled-assimilation system,

the decadal hindcast and prediction experiments yield model-produced "predictions" for each year from 1961 to 2011. These simulations seek to evaluate whether predictive skill for near-term (decadal) climate forecasts is increased when starting from the observed state of the climate system, in addition to the predictive skill that arises from changing radiative forcing. Preliminary assessments of the predictive skill in these simulations reveal that they have skill that is at least comparable to other international efforts. The output from these simulations will be made freely available as part of the Intergovernmental Panel on Climate Change (IPCC) Coupled Model Intercomparison Project Phase 5 (CMIP5).

GFDL also has a vigorous effort to develop and use climate models of much higher spatial resolution to study issues of climate variability, predictability, and change. The GFDL CM2.5 climate model has a 50 km atmospheric resolution and ocean resolution varying from 27 km near the Equator to 9 km at high latitudes. The GFDL CM2.6 climate model has an atmospheric resolution similar to that of the CM2.5 model, but its ocean resolution varies from 10 km at the equator to 3 km at high latitudes. These models use the very latest numerical techniques to provide extremely energetic, realistic simulations of the climate system. Such fine resolution ocean models are world leaders. Through their use, GFDL seeks to further scientific understanding of the role of the ocean in climate variability and change. Preliminary decadal prediction experiments with the CM2.5 model have begun, although the CM2.5 model is approximately 30 times more computationally expensive than the CM2.1 model. Despite this cost, GFDL scientists believe it is critical to move to high-resolution climate models to better understand the causes and predictability of decadal-scale climate fluctuations, as well as the role of the ocean in critical climate change issues, such as oceanic heat uptake.

Great Lakes Environmental Research Laboratory (GLERL)

In FY 2012, 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/Alaska Fisheries Science Center. Financial support for the research is provided by NOAA, NSF, and the North Pacific Research Board.

PMEL also collaborates with ESRL's Chemical Science Division 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 in the

Northwest Pacific report surface meteorological data. A third ocean climate station was established early in 2011 in the Aghulas Current off the southeast coast of Africa.

NASA Supporting Research for Basic Meteorological Services

Research in Basic Meteorology and Atmospheric Science

NASA aircraft and surface instruments calibrate, complement, and expand the value of satellite measurements. NASA supports computing capability and capacity for Earth system modeling. NASA missions produce nearly 4 terabytes of data daily, and NASA maintains the world's largest scientific data and information system for processing, archiving, and distributing Earth system data to worldwide users. International collaborations, including collaborative space missions and joint research efforts, are essential components of NASA Earth Science.

The FY 2012 Budget will fund research competitively selected in FY 2011 through NASA's Research Opportunities in Space and Earth Sciences 2011 (ROSES-11) grant application solicitation. Many of the research activities carried out in FY 2012 will be tasks initiated in FY 2010 and FY 2011 based on the earlier ROSES-09 and ROSES-10 solicitations. Selections based on ROSES-09 and ROSES-10 are ongoing and are addressing diverse Earth Science research areas, including biodiversity, ocean salinity, hurricane and precipitation science, remote sensing of water quality, atmospheric composition, and interdisciplinary science.

Technology Development

Technology investments are aligned primarily with Decadal Survey activities, but may also support NASA's 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. Earth Science Technology Program (ESTP) 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 solicitation, and the duration of each project is typically three years.

For FY 2012, ongoing investigations will be managed in the Instrument Incubator, Advanced Information Systems Technology, and Advanced Component Technology areas. These investigations resulted from the ROSES-10 and ROSES-12 solicitations. ESTP will select Advanced Information Systems Technology projects from proposals submitted in response to the ROSES-12 solicitation.

NASA Applied Sciences Program

The Applied Sciences Program leverages NASA satellite measurements and new scientific knowledge to enable innovative and practical uses by public and private sector organizations. Projects, which are competitively selected through ROSES, are designed to discover and demonstrate new applications and facilitate adoption by non-NASA organizations. In FY 2012 the Applied Sciences Program will continue and initiate projects across a range of application

areas, including health and air quality, water resources, disasters, and ecological forecasting. The Program will feature joint solicitations with research and end-user organizations, contributions to mission science teams, and incorporation of applications requirements throughout the mission design process. NASA will continue the expanded Sistema Regional de Visualizacion y Monitoreo (SERVIR) network and enhance its scientific capabilities across a broader set of Earth science products.

National Science Foundation

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 field campaigns to understand tornadoes, hurricane genesis, and winter storms were conducted over the past few years, and ongoing analyses of these data aim to improve the ability of weather forecasters to relay high-impact weather information to the public.

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 Agricultural Services

The United States Department of Agriculture (USDA) Office of the Chief Economist (OCE) World Agricultural Outlook Board (WAOB) serves as the USDA focal point for economic intelligence and commodity outlooks for U.S. and world agriculture. The WAOB coordinates, reviews, and approves the *World Agricultural Supply and Demand Estimates* (*WASDE*) report. The *WASDE* report provides USDA's forecasts of supply and demand for major U.S. and global crops, as well as for U.S. livestock. 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 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 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 U.S. 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 crops and livestock. The WAOB/JAWF receives a full suite of meteorological data and products from the NWS. WAOB/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 WAOB/JAWF meteorologists use 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 assessments 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, WAOB/JAWF meteorologists prepare special assessments when extreme weather (e.g., droughts, heat waves, freezes, floods, and hurricanes) has been observed or is imminent.

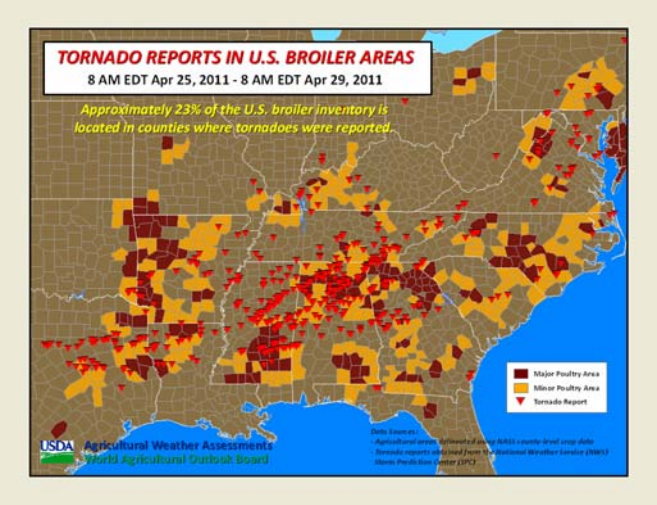


Illustration of a special assessment report GIS.

Many of these special assessments are also prepared using GIS to overlay agricultural and meteorological data. In recent years, the NWS/NCEP, which includes the National Hurricane Center, the CPC, the Hydrometeorological Prediction Center, and the Storm Prediction Center, have supported the WAOB/JAWF by providing an increasing number of their operational products in GIS-compatible formats. These NOAA GIS efforts have benefited the WAOB/JAWF significantly by increasing the speed and efficiency with which agricultural weather assessments can be prepared and enabling WAOB/JAWF meteorologists to more accurately access weather impacts 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 WAOB/JAWF obtains data from the NWS Cooperative Observer Program (COOP) to support domestic agricultural weather applications. The WMO and COOP data are archived at the WAOB using an Oracle database management system. This sophisticated data warehouse helps WAOB/JAWF meteorologists manage the numerous agrometeorological data sets used for agricultural weather assessments.

The JAWF prepares daily agricultural assessments, keeping USDA commodity analysts and the Secretary of Agriculture and top staff informed of worldwide weather conditions and their effects on crops and livestock. Each morning, a written summary of current weather, affecting agriculture in the United States, is sent to the Secretary's office and posted on the JAWF Web site at http://www.usda.gov/oce/weather/pubs/index.htm. Furthermore, alerts of anomalous weather conditions impacting agriculture around the globe are included in a daily report of agricultural developments that is sent to USDA policy makers each afternoon. Inputs from the JAWF are integrated into USDA's monthly foreign crop production estimates. The JAWF provides an objective procedure for translating the flow of global weather information into assessments of crop-yield potential, which are then integrated into USDA's analytical process for estimation of global-area yield and production statistics. These data are then used to evaluate global supply and use estimates.

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 NWS/NCEP/CPC. First published in 1872 as the *Weekly Weather Chronicle*, the publication provides 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 *WASDE* reports, issued by USDA/NASS and USDA/OCE/WAOB, respectively.

Weather conditions impact farming operations, such as planting and harvesting, and greatly influence yield at critical stages of crop development. A wet planting season may prompt farmers to switch to another crop. A poor grain harvest may affect livestock feeding patterns. A regional drought can boost planted acres elsewhere to offset the expected production decline, and government policymakers may adjust farm programs to accommodate changing conditions. As a result, crop and weather information provided in the *WWCB* keep crop and livestock producers, farm organizations, agribusinesses, state and national farm policy makers, government agencies, and foreign buyers of agricultural products appraised of worldwide weather-related developments and their effects on crops and livestock.

Although the main emphasis of the *WWCB* is on current growing-season weather conditions and agricultural developments in the United States, real-time agricultural weather assessments are also provided for foreign countries that are either major exporters or importers of agricultural commodities. These crop-weather assessments keep the U.S. agricultural sector appraised of potential competitors and also influence production decisions at the farm level.

Finally, while the *WWCB* was originally designed to maintain a current awareness of global weather and crop conditions, the long history of the *WWCB* provides an excellent climatological record. This extensive history provides a reference source that is rich in climate and agricultural information, which is essential for episodic-events monitoring and analog-year comparisons.

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 agrometeorological 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), the JAWF, the CPC, the NOAA/NESDIS/National Climatic Data Center, and the Desert Research Institute. Approximately 11 lead authors, two of whom work for WAOB/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/temp-and-precip/drought/nadm/index.html. A U.S. Drought Monitor Forum and a North American Drought Monitor Forum are held in alternating years. These meetings provide an opportunity for Drought Monitor authors, stakeholders, and members of the drought community to discuss the latest drought monitoring tools, drought analyses, and requirements. The most recent U.S. Drought Monitor Forum was held on April 13-14, 2011, at George Mason University. The forum was organized by USDA's OCE, NOAA's Climate Prediction Center, and George Mason University's Environmental Science and Technology Center.

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.* Over the years, the OCE/WAOB played a lead role in developing the NIDIS, working closely with NOAA, the lead Federal agency, and the WGA, to address the specific needs of the agricultural community. Specifically, the 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 was 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 WMO's Commission for Agricultural Meteorology (CAgM). In this position, he advises the current president on projects related to impacts of natural disasters and extreme events on agriculture, and 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/. The Chief Meteorologist also serves as CagM's Coordinator for Global Framework for Climate Services for agriculture.

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) SNOw pack TELemetry (SNOTEL) and Soil Climate Analysis Network (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), the U.S. Geological Survey National Streamflow Information Program (NSIP), and individual state climate offices.

A Remote Automated Weather Station (RAWS).

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.

NIFA funding supports research projects that collect, analyze, and utilize short and long-term weather and climate data as a base of information for the projection and prediction of climatic trends related to environmental impacts on agro-ecosystems, forests, and rangelands and the development of adaptation and mitigation strategies for natural resources and production management. Research, education and extension projects address the contribution of human activities, soil management, and crop and animal production to atmospheric greenhouse gases. Broader areas of study involve climate variability; carbon, nitrogen, and water cycling; and their role in global change. The impact of changes in ultraviolet (UV) and ozone level studies also fit into this broad global category.

Historical climate changes are derived from data gathering and modeling studies, enabling the prediction of future crop production and irrigation needs. NIFA funding supports studies on the impact of climate and weather on food, feed, and fiber production, and on natural resource protection and utilization. These studies relate to forest and agricultural plant growth, rangeland productivity, cropping system selection, livestock production practices, and natural resource management.

Man's impact on climate systems is also well represented in studies of both micro-and macro-climatic change. These studies address the climatic impact on air quality, water quality and quantity, and point/non-point pollution related to agricultural practices, and forest and urban development. NIFA funds also support climatic impact studies on nutrient cycling and carbon sequestration and emission. Additionally, NIFA supports research to quantify the impact of climate change on the incidence and severity of drought, extreme heat and cold, plant and animal diseases and pests, invasive species, biodiversity, and ecosystem services.

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 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) to provide decision-support tools for farmers, ranchers, and land managers that will enable sustainable production under conditions of drought, flood, high temperatures, and short-term temperature extremes. Climate change research is conducted to develop technologies for mitigation of the impacts of agriculture on climate, and from the perspective of adapting agricultural systems for resilience to the impacts of changing climate.

The development of genetic resources for weather-tolerant crops is a foundational element of ARS research. This includes new plant varieties that will combat the insects, pathogens, and weeds that flourish under specific weather patterns and are being enhanced by changing climate. Identification, development, and distribution of genetic material that offers resistance to ozone damage continue to be a top priority.

Since a significant amount of food production is currently made possible because of irrigation, ARS conducts weather research focused on irrigation scheduling, increased efficiency of water use, and watershed management. Also, evapotranspiration (ET) monitoring, and the incorporation of this information from in situ and remote sensing systems into irrigation scheduling algorithms, are under development at ARS. This work includes collaborative research with scientists at NOAA, NASA, OCE/WAOB/JAWF, and land grant universities to use satellite-based ET information for drought maps and to elevate the importance of ET as an important variable for climate change science. ARS scientists are also leaders in the development of algorithms for soil-moisture mapping satellites to be launched by NASA and international collaborators. ARS scientists also conduct research to understand and manage emissions of particulate matter, volatile organic compounds, greenhouse gases, and other materials from agricultural sources and landscapes that affect air quality.

Weather and climate information needed to develop strategies for the reduction of soil loss and sedimentation of water bodies, and for prediction of flooding occurrence, is 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 COOP Network to ensure the information needs of agriculture are addressed by the national surface observation network. Discussions are underway to use ARS experimental watersheds as a baseline for the development of a Long-Term Agricultural Research network because of the strong emphasis on weather and climate research for agriculture by these locations. 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

U.S. Code Title 49 Section 44720 (49 U.S.C. 44720) designates the Federal Aviation Administration (FAA) as the Meteorological Authority for aviation weather services for the United States. In this capacity, the FAA provides requirements for the provision of aviation weather services to the National Weather Service (NWS), which is designated as the National Meteorological and Hydrological Service Provider. The FAA is responsible for ensuring compliance with the services as defined and with maintaining International Civil Aviation Organization (ICAO) Standards and Recommended Practices as specified in Annex 3, Meteorological Service for International Air Navigation.

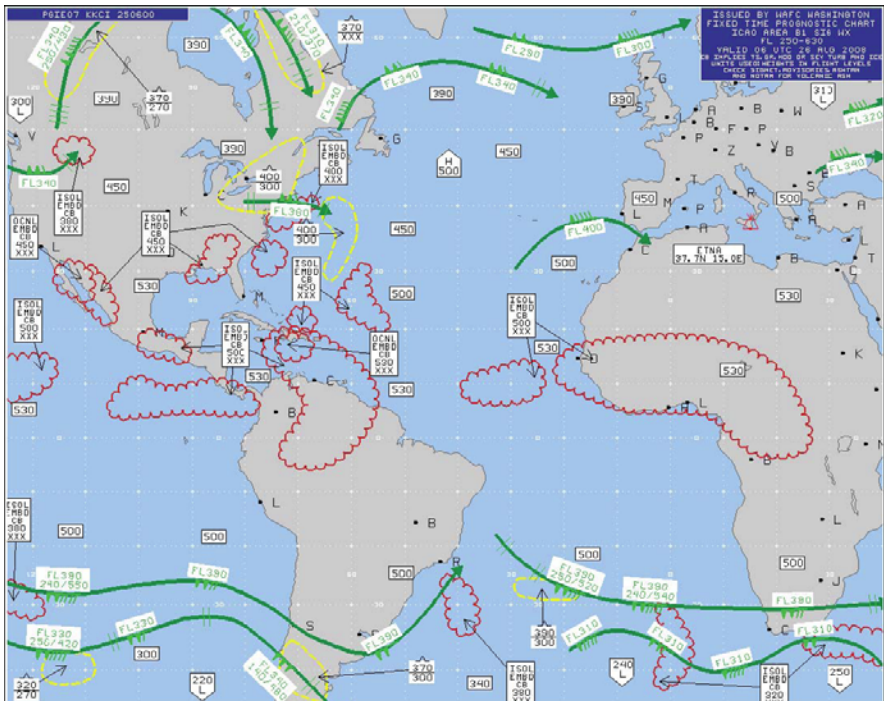
The Department of Defense (DOD) service branches (U.S. Army, Navy, Air Force, and Marine Corps) provide their own aviation weather support services while abiding by Federal and international regulations. Each military service has its own meteorological support personnel except the Army, which is supported by the Air Force. Please refer to the Military Services section for details of military-unique aviation weather services.

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

NOAA/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 from the FAA and the international community, aviation weather products issued by NWS span the globe.

Under an international agreement through the ICAO, the United States meets its weather forecasting obligations to the aviation community through products and services of the Aviation Weather Center (AWC), one of the National Centers for Environmental Prediction (NCEP) 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 these conditions. The forecast charts also include information on volcanic activity, radiological releases, jet streams, and tropopause heights. This information is transmitted by the International Satellite Communications System (ISCS), a satellite data distribution system operated by NWS, with coverage in the Americas, Caribbean, Atlantic, western portions of Europe, the Pacific, and Eastern Asia.



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.

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. This information is transmitted via the ISCS in support of the World Area Forecast System (WAFS) for ICAO aviation data needs and in support of World Meteorological Organization (WMO) Region IV (North America) data exchange requirements. Starting in 2011, the ISCS is being supplemented with the WAFS Internet File Service (WIFS) to provide WAFS products and services, as defined by ICAO Annex 3, in an Internet web-based medium. ISCS will be phased out in 2012.

In addition to satisfying these global requirements for aviation weather, AWC hosts the Aviation Digital Data Service (ADDS), which makes available to the aviation community text, digital, and graphical forecasts, analyses, and observations of aviation-related weather variables. The ADDS serves as a platform for aviation weather products emerging from the FAA Aviation Weather Research Program and transitioning to operations. It has become an invaluable resource to users, especially in the U.S. general aviation community. In 2011, AWC launched a new website infrastructure that capitalizes on its FAA certification as a Qualified Internet Communications Provider. The enhanced web presence provides increased levels of data reliability for uses.

The United States, in agreement with ICAO, operates two Volcanic Ash Advisory Centers (VAACs) as entities within NOAA. One of these, the Anchorage VAAC, is part of the AAWU located in Anchorage, Alaska, and works closely with the Alaska Volcano Observatory. The

second VAAC, which is part of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) and NCEP, is located in Camp Springs, Maryland. The VAACs monitor volcanic activity through satellite remote sensing, provide initial notification of a volcanic eruption upon detection, and forecast volcanic ash plume movement and evolution.

Under an agreement with the FAA, 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. Because CWSU forecast support is embedded within the aviation mission, forecasters can focus on specific customer needs. In one example, a specialized marine stratus display system was developed to address the difficult issue of fog formation and dissipation in the San Francisco Bay Area. The San Francisco stratus system is used operationally by the CWSU forecaster, WFO aviation forecaster, FAA traffic managers, and airline meteorologists.

To operationally support the needs of aviation users today, the NWS WFOs prepare Terminal Aerodrome Forecasts (TAFs) eight times daily, 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 NWS, through the NCEP AWC, the AAWU, the two VAACs, and the Honolulu WFO, provides large-scale, global aviation functions that can be sensibly centralized, while the NWS WFOs discharge local aviation functions based on the centralized guidance provided by the AWC. Additionally, NCEP's Environmental Modeling Center (EMC) 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. NWS's NextGen Weather Program provides funds for the development and implementation of improvements to accuracy and accessibility of aviation weather information, aimed at meeting the goals of the Next-Generation Air Transportation System (NextGen).

Federal Aviation Administration

Aviation Weather Observations

Automated Surface Weather Observation Network (ASWON)

ASWON is the FAA's overarching program for providing automated weather observations at airports. The system includes eight separate programs: (1) the Automated Weather Observing System (AWOS), (2) Automated Surface Observing System (ASOS), (3) ASOS Pre-Planned Product Improvement (P3I) project, (4) Automated Weather Sensor System (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.

The ASOS P3I is the only remaining active development program within the ASWON portfolio, whereas the other programs are in service. 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 efforts, only the Ceilometer Replacement and the EPI sensor remain in development. The ASOS P3I program is managed by the NWS under an Interagency Agreement.

AWOS. The FAA's AWOS provides basic aviation weather observations directly to pilots approaching the airport. The majority of the 182 AWOS units installed are located at non-towered airports. They 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.

ASOS. The tri-agency (FAA, NOAA/NWS, and DOD) ASOS program is described above, in the Basic Services section. As noted there, about 426 ASOS units are installed at towered airports where the FAA provides augmentation/backup for the observations (see Observation Service Levels discussion below). The remaining units are installed at non-towered airports (Observation Level D).

AWSS. This automated observing system has capabilities similar to ASOS. However, the AWSS was a direct acquisition of the FAA rather than an acquisition through the joint ASOS program. Commissioning of the original 19 AWSS installations was completed in 2005. Observation Level C service is available at 7 airports, and Level D service is available at 12 airports. An additional 25 AWSS have been installed at airports in Alaska as part of the ADS-B/Capstone program.

ADAS. ADAS functions primarily as a message concentrator, collecting observation data from AWOS, ASOS, and AWSS equipment located at controlled and noncontrolled airports within each ARTCC's area of responsibility. ADAS distributes one-minute AWOS/ASOS observations to automated systems. It also collects data from a lightning vendor and enters the data into an ADAS module called the Automated Lightning Detection and Reporting System (ALDARS). ALDARS appends thunderstorm information to observations at 569 ASOS, 19 AWSS, and 180 Federal AWOS locations. ADAS forwards the AWOS/ASOS/AWSS METAR and SPECI observations to the communications system for further distribution.

Observation Service Levels

The FAA has added services 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.

ASOS Level D Service. Level D Service is provided by a stand-alone ASOS. Level D service is available at 458 airports.

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.

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 58 airports.

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 72 airports.

Stand Alone Weather Sensors

The SAWS project was initiated in 1998 as one of eight projects for ASWON. SAWS systems provide temperature, dew point, wind speed and direction, and barometric pressure for altimeter settings. The systems were installed primarily as a backup for AWSS/ASOS sensors at Service Level C airports where no other backup capability is available. In addition to serving as an AWSS/ASOS back-up, SAWS has 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 DASIs. SAWS capability has been demonstrated, production is complete, and the FAA has 131 SAWS systems installed and commissioned.

AWOS for Non-Federal Applications

Under the Airport Improvement Program (AIP), State and other local jurisdictions may justify to the FAA the need to enhance their airport facilities. Upon approval, these improvements can be partially funded by the FAA using resources from the Airway Trust Fund. The local airport authority becomes responsible for the remainder of the funding necessary to complete the procurement, as well as the funding for regular maintenance. Addition of an AWOS is one of the improvements that qualify for AIP funding assistance. Airports can also use State, local or private funds to purchase 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, A/V, I, II, III or IV variants. Some of these—the AWOS III and AWOS IV variants—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.

Weather And Radar Processor (WARP)

The WARP system was designed to close an identified performance gap in providing accurate and timely weather information by replacing the long-range surveillance radar weather reflectivity data with more accurate information from the Next Generation Weather Radar (NEXRAD; WSR-88D) system. Accurate weather information presented in an integrated manner in the en route environment gives air traffic controllers a comprehensive picture of where aircraft can safely fly while making the most efficient use of airspace. The WARP system enhances safety, reduces weather-related delays, and improves collaborative decision-making.

The WARP system is operational at the 21 ARTCCs and at the Air Traffic Control System Command Center (ATCSCC). Each operational WARP system consists of a number of subsystems, which together perform the following primary WARP functions:

- Integrate timely and accurate convective weather onto air traffic controller displays
- Support to the Traffic Management Unit and to air traffic control specialists at the ARTCCs and the ATCSCC with a wide variety of weather data
- Disseminate weather data to critical NAS subsystems
- Provide current and forecast data to CWSU meteorologists, and a communications link to supported air traffic personnel

These WARP weather functions furnish timely, accurate, and integrated weather products to other NAS systems.

A WARP technical refresh is addressing the aging infrastructure of the existing WARP hardware and software systems. Refresh 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 (ERAM) and Advanced Technologies and Oceanic Procedures (ATOP) systems.

WARP maintenance and sustainment activities will continue, and efforts will be initiated for the incorporation of data format changes as well as ongoing required information systems security activities. The WARP system will continue to be sustained until the equivalent functionality in the NextGen Weather Portfolio is deployed.

WARP continues to support the FAA goal of greater capacity, as set forth in *Destination 2025: the FAA Strategic Plan:* work with airspace users to provide increased capacity in the U.S. airspace system that reduces congestion and meets projected demand in an environmentally sound manner.

Wind Shear Detection Services (WSDS)

WSDS is a portfolio of ground-based wind shear technologies in the NAS, divided into two work packages (WPs). WSDS will sustain existing wind shear service until 2028 and also improve wind shear service by leveraging new wind shear technology such as Wind Hazard Detection

Equipment (WHDE, formally referred to as Light Detection and Ranging, or LIDAR) and by expanding wind shear service to unprotected and underprotected sites in a cost-effective and cost-efficient manner.

The WP1 (Legacy) package contains the Low Level Wind shear Alerting System (LLWAS), Weather Systems Processor (WSP), and Terminal Doppler Weather Radar (TDWR). These three legacy wind shear technologies are nearing the end of their service life and are in need of either a Service Life Extension Program (SLEP) or a Technology Refresh to ensure that existing wind shear performance levels are sustained until the NextGen wind shear technology is available. WP2 consists of new and innovative wind shear technology such as WHDE and will expand wind shear service to unprotected and underprotected sites.

The WSDS program will accomplish its goals by constructing a business case to evaluate the existing wind shear systems and determine how best to maintain wind shear service until the NextGen windshear service is fully implemented. After ensuring that existing wind shear service levels will be properly maintained, the WSDS program will turn its attention to modernizing, improving, and "right-sizing" wind shear service as a whole.

The output of the business case will be recommendations to FAA executives on how to maintain existing wind shear service levels and how best to improve wind shear service in a cost-effective and cost-efficient manner that will translate into benefits that can be realized by both the FAA and the flying public.

WSDS supports the FAA goal of Provide Weather Products: provide program management for capital acquisitions aimed at increasing safety. These investments for FY 2011 include WSDS portfolio, WP1.

A Terminal Doppler Weather Radar

Terminal Doppler Weather Radar

The TDWR program consists of operational, dedicated aviation terminal weather radars that employ Doppler techniques to detect weather phenomena. TDWR units have been located to optimize the detection of microbursts and wind shear at selected airports with high operations and frequent weather impacts. In addition, TDWR has the capability to identify areas of precipitation and the locations of thunderstorms. The FAA has 45 operational and 2 support TDWR systems.

Microbursts are weather phenomena that consist of an intense downdraft with strong surface wind outflows. They are particularly dangerous to landing or departing aircraft. The TDWR scanning strategy is optimized for microburst/wind shear detection. The radars are located near airport operating areas so as to

provide the best scan of runways and the approach and departure corridors. System displays are located in the tower cab and Terminal Radar Approach Control Facility.

The TDWRs provide wind shear alert conditions for airport approach and departure advisories. They also 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 Network Expansion (LLWAS-NE) systems supplement the microburst detection capabilities of the TDWRs at nine airports.

The NWS developed an interface so the TDWR data can be displayed on the Advanced Weather Information Processing System (AWIPS) and shared through the NWS national collection point. A SLEP is underway to maintain and improve TDWR system capability.

Integrated Terminal Weather System (ITWS)

The FAA developed ITWS to help air traffic flow more efficiently during periods of bad weather. ITWS provides accurate, easy-to-understand, and immediately usable weather information on full-color graphic displays. It uses input data from TDWR, NEXRAD, Airport Surveillance Radar Models 9 and 11 (ASR-9, ASR-11), LLWAS, AWOS, and ASOS. Other inputs come from the National Lightning Detection Network, the NWS Rapid Update Cycle (RUC) forecast model, and aircraft reports from the Meteorological Data Collection and Reporting System. It combines these data with highly sophisticated meteorological algorithms to display current and predicted weather and warnings of potentially hazardous weather events, from the airport's location out to 200 nautical miles.

ITWS products include information on windshear, 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 predictive products from 20 to 60 minutes. This enhancement provides additional data to assist air traffic personnel in using forecast information more effectively.

The FAA installed and commissioned ITWS at 34 operational sites that serve 76 airports, 29 of which are Operational Evolution Partnership (OEP) Level 1 airports. ITWS Situation Displays are installed in 15 Secondary Reliever airports, and ITWS displays are located in air traffic control towers, terminal radar approach control facilities, and ARTCCs. ITWS Situation Displays, as well as 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.

FAA benefits studies have shown that the 34 installed ITWS systems are generating significant benefits for both traffic flow and airlines. 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 convective weather. ITWS provides the benefits of common situational awareness, collaborative decision-making, and tactical planning for its users. For example, the current and future predicted locations of convective weather around airports, which affects both airborne and ground operations, can be used to keep runways open longer as the weather

approaches and then to reopen runways sooner after the weather passes, allowing more takeoffs and landings. These efficiencies increase effective capacity and reduce weather delays for airlines and the traveling public, saving time for the flying public and money for the airlines.

In February 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; and
- The original ITWS business case, which defines ITWS functionality, cost, and benefits, continues to be valid.

ITWS is an FAA NextGen Contributor program and directly supports the Reduce Weather Impact (RWI) and NextGen Network Enabled Weather (NNEW) initiatives within NextGen. On behalf of the FAA, via an Intra-Agency Agreement, the John A. Volpe National Transportation Systems Center is leading the development effort for the Terminal Data Distribution System and hosting ITWS in order to facilitate the exchange of critical flight information as part of System Wide Information Management (SWIM). With 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 capability became operational in January 2011.

Via a separate Intra-Agency Agreement, the 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.

Weather Camera Program

The FAA has installed aviation weather cameras as an aid to Visual Flight Rules (VFR) pilots operating in Alaska. Through the cameras and the Internet, pilots get a current picture of the weather conditions to assist them in making flight decisions. There are over 150 camera sites installed and operating, with an additional 24 requested for FY 2012.

Juneau Airport Wind System (JAWS)

JAWS provides data on terrain-induced wind and turbulence to improve safety of flight and decrease the probability of experiencing unnecessary weather-related delays in and out of the 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. 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 Alaska aviation users access JAWS data via the Internet.

JAWS supports the FAA goal of Provide Weather Products: provide program management for capital acquisitions aimed at increasing safety. The FY 2011 investments included JAWS–Harden Prototype and Implementation. The National Center for Atmospheric Research (NCAR) developed the prototype JAWS and has been operating and maintaining the prototype since 1998. A December 2008 investment decision approved implementing a hardened prototype as the end-state JAWS which is planned for completion in early 2012. The end-state JAWS will be operated and maintained by the FAA, with NCAR providing operations and maintenance history and technical support during the transition.

National Volcanic Ash Operations 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, National Aeronautics and Space Administration (NASA), NOAA, U.S. Geological Survey (USGS), the U.S. Air Force, and the Smithsonian Institution. The WG/VA has prepared a National Volcanic Ash Operations 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. This document also provides information on how the FAA, as the U.S. metrological authority with regard to the ICAO, meets its obligations to the International Airways Volcano Watch, which is sponsored by the ICAO. There are several 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 (Washington and Oregon) was completed in 2011. Regional plans typically also involve State and local agencies.

USGS. Through its five Volcano Observatories, the USGS is responsible for monitoring volcanoes in the United States and issuing notifications about volcanic activity as it waxes and wanes at individual volcanoes. USGS Volcano Observatories use a combination of ground-based, airborne, and space-based techniques to interpret precursory unrest and forecast expected volcanic activity (including when eruptions are not expected). Data and notifications of eruptive activity from USGS monitoring activities are supplied to FAA and DOD to provide warnings for pilots and aircraft operators and to NOAA/NWS to aid in its forecasting and tracking of ash clouds. 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. USGS notifications and warnings about current volcanic

Volcanic ash hazards can be catastrophic to aviation operations.

activity throughout the United States are available to the public at http://volcanoes.usgs.gov/.

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, as well as with ICAO, to improve capabilities in mitigating the impact of the presence of volcanic ash in busy flight routes, both domestic and international. USGS also has established a new project that focuses exclusively on volcanic ash and brings together USGS efforts in research and development of new operational tools. One element of the new project is to collaborate with the NWS in Alaska on improving ash fall warnings for the public. The USGS 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.

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)" (available 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.

NASA. Through its fleet of satellite assets, NASA is able to rapidly generate and broadly disseminate imagery and data products on the location, heights, and densities of ash plumes and related hazards. These data products fuel a range of research and applications investigations that enhance our knowledge of solid Earth processes, atmospheric transport and composition, and the impacts that volcanic eruptions have on the Earth system. Although NASA does not have operational responsibility for observation and analysis of volcanic gas and aerosol emissions, its fleet of research spacecraft provides data that are directly applicable to the societal hazards presented by these phenomena.

NASA's Earth Science Division currently operates three on-orbit sensors that monitor volcanic ash, gases, aerosols, and eruptions. NASA plans to launch a new satellite in 2011 to build on this capability. The three sensors currently on orbit are the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation satellite (CALIPSO), a joint mission between NASA and the French space agency CNES; the Ozone Monitoring Instrument (OMI)—a contribution of the Netherlands's Agency for Aerospace Programs (NIVR) in collaboration with the Finnish Meteorological Institute (FMI)—onboard the Aura satellite; and the Moderate Resolution

Imaging Spectroradiometer (MODIS) onboard the Terra and Aqua satellites. NASA-built sensors on NOAA Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES) also support volcanic ash monitoring. NASA launched the NPOESS Preparatory Project (NPP) satellite on October 28, 2011. Onboard NPP are the Visible Infrared Imaging Radiometer Suite (VIIRS) and the Ozone Mapping and Profiler Suite (OMPS) to augment NASA's current capabilities.

NOAA. NOAA/NWS is responsible for volcanic ash services in the United States. The program is currently managed under the Aviation Services Branch at NWS Headquarters in Silver Spring, Maryland. Although the main focus has been and continues to be on the airborne ash hazards (mainly impacting aviation), there has been a move in the past several years to expand into an "all hazards" approach that incorporates both the NWS Public and Marine Services programs. The NWS is a co-lead in the development of regional volcanic ash response plans in the United States. Plans are currently in place for Alaska, the Pacific Northwest (Washington, Oregon), and the Northern Marianas Islands. Future plans are being developed for Hawaii, California, and Puerto Rico/Eastern Caribbean. These plans are available on the OFCM web site at www.ofcm.gov. As noted earlier, NOAA/NWS also operates the Anchorage VAAC and partners with NESDIS to operate the Washington VAAC—two of the nine such international centers.

NOAA/NESDIS is responsible for providing satellite data used in detecting and tracking volcanic ash in the atmosphere and is dedicated to providing timely access to global environmental data from satellites and other sources to promote, protect, and enhance the Nation's economy, security, environment, and quality of life. Many of the operational environmental satellites operated by NESDIS (see NOAA/NESDIS in Basic Services section) have channels available to help forecasters detect and track volcanic ash. The GOES-R and JPSS programs are joint NOAA-NASA programs that will provide more frequent, higher resolution imagery for the detection and tracking of volcanic ash beginning in 2015.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

The National Airspace System 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 VISION 100 Century of Aviation Reauthorization Act (P.L. 108-176). The Vision 100 Act calls for an integrated, multi-agency plan to transform the nation's air transportation system to meet the needs of the year 2025 and beyond, 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.

Joint Planning and Development Office (JPDO)

The FAA, NASA, and the Departments of Commerce, Defense, Homeland Security, and Transportation, along with the private sector and academic community, 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 the JPDO is the Weather Working Group, which facilitates integrating longer-term planning.

NextGen Integration and Implementation Office

Two principal FAA entities that report to the Senior Vice President for NextGen and Operations Planning are focused upon implementation of NextGen: 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 NNEW and the RWI Solution Set. NNEW is a transformational program that will address the weather dissemination infrastructure within the Air Navigation Service Provider. RWI is focused on improving weather observations, weather forecasts, and operational decisions based upon that improved weather information by integrating it into manual and automated decision support tools in the NAS. In addition to working with the AWG, the RWI Solution Set coordinates the investment analysis and acquisition of new weather systems and services within the FAA's Aviation Weather Services Directorate, NOAA/NWS, and other JPDO agencies.

FAA AWG and AWSD Roles in NEXTGEN Transition

The AWG and AWSD 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.

The AWSD develops mission need and investment analysis for initial investment decisions for FAA aviation weather sensors, forecasting capability, dissemination systems, and integration of improved weather capability into the NAS. The focus is on NextGen, including collaboration with Single European Sky ATM Research (SESAR), with ICAO for advanced aviation weather standards, and with all the U.S. agencies involved in NextGen. This work addresses the high cost of weather to today's NAS, where weather is responsible for 70 percent of delays over 15 minutes and contributes to 24 percent of accidents and 34 percent of fatalities. Up to two-thirds of weather delays are avoidable, but despite a continuous flow of improvements available through aviation weather science and implementation solutions aimed at providing better weather information, weather continues to have significant impacts on aviation costs and safety. The purposes of this program are to reduce the number of weather-related aviation accidents; reduce aviation flight delays, diversions, and cancellations; improve the operational efficiency of the NAS; and harmonize ICAO standard with U.S. practices in aviation weather.

The NextGen program in AWSD is composed of three elements:

1. The Concept Identification and Development component generates, analyzes, manages, allocates, and validates requirements in the NextGen aviation weather portfolio. It focuses on the early stages of requirements from their inception/generation to the investment

analysis and subsequent requirements decision. It develops transformational (NextGen mid-term and far-term capabilities), as well as evolutionary requirements (NextGen near-term capabilities). It formulates agreements between government and industry stakeholders on policies needed to meet requirements for airborne weather observations, including cost sharing, data access and distribution, data reporting frequency, aircraft equipage, and other technical issues. Finally, this program develops policies necessary for the allocation of roles and responsibilities in the provision of weather state information to meet requirements and U.S. commitments to ICAO.

2. The Global Harmonization component carries out FAA's role as the U.S. Meteorological Authority to ICAO. It promotes global harmonization through the development of ICAO Standards and Recommended Practices and manuals/guideline documents for surface and airborne observations/forecasts and global dissemination of aviation weather information that are supportive of NextGen. This work is accomplished through developing and presenting, to 12 ICAO planning, study, and operations groups, U.S. positions on issues arising from the ICAO Volcanic Ash program, the World Area Forecast System, the international Space Weather program, and amendments to ICAO Annex 3 and other guidance material to incorporate the NextGen concept of the 4-D Weather Data Cube.

3. The System Performance component develops metrics that provide a framework for enabling the FAA to measure the benefits of weather information for air traffic operations. It maintains standards for surface observations for the backup and augmentation of ASOS.

The development of NAS weather requirements under this program is an essential artifact of the following NextGen documents: the Weather Concept of Operations, the Mission Needs Statement for Weather (MNS-339), the Preliminary Portfolio Requirements, and the Final Portfolio Requirements. The requirements work in this program feeds later-stage activities, as defined by the FAA Acquisition Management System (AMS) lifecycle, of the RWI and NNEW portfolios.

The Reduce Weather Impact Portfolio

RWI is a planning and development portfolio to ensure NextGen operational weather capabilities utilize a broad range of weather improvements and technologies to mitigate the effects of weather in future NAS operations. This portfolio has two major elements: weather observation improvements and weather forecast improvements. RWI will address many weather 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 the NextGen near, mid, and far terms.

A consistent and effective weather observation sensor network will be a cornerstone to improved NextGen weather capabilities. Currently the United States has fielded multiple weather surface sensor networks that vary in age up to 30 years. Ongoing technical refreshes and SLEPs can keep

these sensors operating in the near to mid term. However as the demands of the NAS increase in the future, the present array of surface sensor systems will not be capable of delivering the required functionality. In addition, potential NextGen weather observation requirements might exceed current surface sensing capabilities (e.g., improved weather model initialization for increased weather forecast accuracy). Current surface observation systems also contain considerable overlap and waste that should be engineered out of the NAS. RWI weather observation improvements will explore concepts for a next-generation surface sensing capability that can satisfy all current surface sensing requirements in a single system and be easily expandable to meet any future NextGen requirements.

The second RWI element, weather forecast improvements, addresses the need to enable better weather decision-making and use of weather information in the transformed NAS. This need 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 effectively used in air traffic and traffic flow management, and (5) determining the most effective solution for a processor architecture to support these capabilities. RWI will propose recommendations for near, mid, and far time frames, including a recommendation for transition of legacy systems.

Collectively the effect of the NextGen RWI portfolio will result in aviation weather information no longer being just a stand-alone display, requiring cognitive interpretation and impact assessment, with limited ability to significantly mitigate delays. Instead, weather information is being designed to integrate with and support NextGen decision-oriented automation capabilities and human decision-making processes.

The NextGen 4-Dimensional Weather Data Cube and Single Authoritative Source

NextGen weather development activities will contribute to: (1) *Expanded Capacity* by providing air traffic managers the ability to better plan for predicted weather impacts on air travel, thus maximizing air space usage and optimizing flight routes; (2) *Improved Safety* by providing pilots and air traffic managers the ability to better assess and avoid hazards to air travel, such as severe turbulence, and (3) *Protection of the Environment* by enabling flight route optimization on the ground and in the air, thereby avoiding ground delays or holding patterns that require unnecessary jet fuel expenditure.

NOAA's commitment to the NextGen initiative will result in the development and deployment of the NextGen 4-Dimensional (4-D) Weather Data Cube. The "4-D" references weather from the surface up to aircraft flight altitudes, extending north-south and east-west, and including current and future conditions. This Data Cube is not a physical database; instead it refers to data having the following characteristics:

a. Improvements to information technology infrastructure comparable to those already employed by other governmental agencies and by industry to provide greater and easier access to NOAA weather information for aviation decision-makers. Greater access to aviation-relevant weather information will facilitate better integration of this information into aviation users' decision-making processes and systems.

b. More consistent aviation weather information, providing a complete picture of how weather will impact aviation across NAS.

c. Improvements to the accuracy of weather information. More accurate aviation weather information, achieved through higher resolution weather models, will improve air traffic managers' ability to fine-tune their assessment of the impact of the weather on airports and air routes to safely maximize available air space.

d. Improvements to aviation forecast generation techniques. NWS meteorologists require advanced tools and techniques to enable faster, more accurate generation of aviation weather information.

The NextGen Single Authoritative Source (SAS) identifies the preferred, consistent data source to be used to support collaborative air traffic management decisions. It is an optimal representation of all Air Navigation Service Provider (ANSP) weather state information derived from the NextGen 4-D Weather Data Cube. A subset of the data published to the 4-D Weather Data Cube will be designated as the SAS. The SAS will be consistent in time, space, and among weather elements and will be used directly or translated into products with operational impact by the ANSP. The SAS will be specified by the ANSP and will be accessible to all users of the NAS. The ANSP will specify characteristics of weather state information needed to support its ATM decision-making and the corresponding decision support tools. As NextGen capabilities mature, the ANSP requirements will evolve. The NWS will, in coordination with the U.S. Air Force and Navy weather services, determine what weather state information best meets the 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.

With rare exceptions, the 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 decision-makers, such as pilots, dispatchers, and military operators. Making the SAS both a support tool for the ANSP's ATM decisions and a NextGen resource provides both transparency and predictability in these decisions and shared situational awareness for all NextGen participants.

The NextGen Network Enabled Weather Program

NNEW is part of an interagency effort to provide quick, easy, and cost effective access to weather information by all aviation users. NNEW will define and provide the FAA's portion of the interagency infrastructure used to support the 4-D Weather Data Cube, which will contain all relevant weather information needed to support operational aviation decisions by the FAA. The 4-D Weather Data Cube consists of weather data published in various databases within FAA, NOAA, and DOD, as well as commercial weather data providers that may participate. NNEW provides: (1) registries/repositories needed to locate and retrieve published data in the Data Cube, (2) the capability to translate among various standards that will be employed and to provide data in user-required units and coordinate systems, and (3) the capability to support retrieval requests for data volumes (such as along a flight trajectory).

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 traffic management. The primary objectives of the WTIC program are to: (1) reduce workloads for pilots, flight crews, and the ATM in support of efforts to increase NAS capacity; (2) support NextGen and other near-, mid-, and far-term programs needs for the availability of enhanced meteorological (MET) information; (3) eliminate MET information gaps and meet user needs; to more efficiently use existing data link bandwidth; and (4) reduce ambiguity in transmitted MET information. Additional objectives are (1) to support increased efficiency via timelier decisions in adverse weather and more optimum routes from enhanced wind and temperature information and (2) to reduce the likelihood of recurrence of specific weather-related incidents, including those reported in the Aviation Safety Reporting System as well as other safety reporting systems.

The initial WTIC research evaluated the overarching NextGen Concept of Operations and requirements for NextGen weather support on the flight deck, identified the current capabilities to meet NextGen requirements, evaluated planned and funded development of new weather support capabilities, and identified gaps between NextGen requirement and current developing weather support capabilities. Since WTIC requires data links to support the dissemination of MET information to users in various coverage environments, the program is researching required data link capability for bandwidth, security, quality of service, and reliability. Based on the results of this WTIC research, the program will develop functional and performance requirements for cockpit integration of MET information; guidance on the rendering of MET information in the cockpit; and recommended data link architectures for uplinking, downlinking, and crosslinking MET information.

In addition, WTIC human factors research will enable the development of human performance, technology design, and human-computer interaction requirements and standards to enable safe, efficient, and cost-effective operations and training. The human factors research will attempt to identify shortcomings in current capabilities in order to focus weather technology advancements on optimizing safety and efficiency for flight operations under Parts 91, 121, and 135 of the Federal Aviation Regulations.

The information management and human factors research deliverables will enable the development of Air Circulars and Orders for NextGen training, symbology, and information standards; support the development of aircraft certification 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, the WTIC program research will support the development of the communications information management to include storage and retrieval requirements and standards to acquire MET information from commercial and government-provided graphical and textual databases.

NextGen Wake Turbulence

This research has the objective of determining the NAS infrastructure requirements (ground and aircraft) for implementing the NextGen trajectory-based operations and high density concepts within the constraints of aircraft-generated wake vortices and aircraft collision risk.

FAA Research and Development: The Aviation Weather Research Program

The Aviation Weather Research Program (AWRP) will continue research into understanding the geophysical phenomena in the atmosphere and around airports that present hazardous conditions for aircraft operations. These hazards include in-flight icing, convective weather, turbulence, low ceiling, restricted visibility, volcanic ash, summer and winter storm activity, and others. Additional work is being done to improve models and develop advanced weather radar techniques.

In-Flight Icing

This research is aimed at developing improvements to in-flight icing diagnosis, which includes detection and forecasting. The Current Icing Product (CIP) and Forecast Icing Product (FIP) have been developed to provide hourly updates of current and forecast conditions out to 12 hours. These products include severity and probability of icing conditions and supercooled large drop potential. Planned efforts include expanding the CIP and FIP to Alaska and globally (oceanic routes).

Convective Weather

Research efforts for convective weather are targeted to developing an advanced storm prediction algorithm over the continental United States to provide more accurate structure depiction (including growth and decay), with longer lead times, of hazardous convection and winter storm activity so that ATM decision makers can make enhanced decisions relative to traffic flow. These efforts will also improve safety near thunderstorms. Fuzzy logic forecast technology, coupled with numerical weather predictions and climatology, is utilized to produce a blended 0-8 hour and beyond forecast. These forecasts will also enhance the capability to predict storm growth, real extent, movement, and type of precipitation. Probabilistic forecasts are also being developed to enable more accurate traffic flow management decisions and more efficient use of the NAS.

Turbulence

This research has focused on producing a system of real-time turbulence nowcasts and probabilistic forecasts of turbulence. The approach 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 NEXRAD, will be used as input in the production of the Graphical Turbulence Guidance Nowcast (GTGN) product.

National Ceiling and Visibility (NCV)

The Ceiling and Visibility Product Development Team is developing automated ceiling and visibility products to support current needs and future NextGen requirements for improvements in general aviation safety and terminal area traffic flow efficiency. Current NCV work focuses on development of (1) a real-time deterministic nowcast presenting current ceiling, visibility, and flight category fields (the Ceiling and Visibility, Analysis; or CVA), and (2) hourly-updated probabilistic 1–10 hour forecasts of these same fields (the Ceiling and Visibility, Forecast; or CVF).

Volcanic Ash Dispersion Forecasts

Research efforts in this 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 potential hazardous conditions. In addition, both the VAACs and Meteorological Watch Offices will have this information made available in support of 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 a set of volcanic ash current performance parameters and requirements. The outputs of these requirements will be leveraged with other agencies toward developing an ensemble approach aimed toward implementation in ATM operations and other basic services.

Quality Assessment

This research team conducts verification and assessment activities to support all AWRP algorithm development activities and NextGen implementation. Quality Assessment evaluations of weather research capabilities use the Real-Time Verification System (RTVS). This system supports real-time forecast operations, development, and case study assessments. RTVS provides a mechanism for monitoring and tracking improvements to weather forecast products with an independent assessment of forecast quality. Its outputs are thus valuable as support for decisions on whether to move weather products into operations.

Model Development and Enhancement

This is a multi-agency task that has partial funding from Aviation Weather (see Basic Services for more information).

Advanced Weather Radar Techniques (AWRT)

This research is aimed at developing techniques for using weather radar data to improve aviation weather forecasting. Information developed by these efforts is used by the other AWRP weather research teams and other agencies to improve their forecast and nowcast products. Current AWRP funding is producing applications to enhance traditional ground-based observations and improve the monitoring and prediction of hazardous weather. With support from the emerging WTIC Program, new AWRT work will examine improving the availability of weather radar information in the cockpit.

Also receiving AWRP funds is the development of the Multi-Radar Multi-Sensor (MRMS) capability, which will provide high resolution 3-D radar grids for advanced weather detection and forecast applications. MRMS output is typically directed toward specific applications developed within other AWRP Product Development Teams, such as the In-Flight Icing, Modeling, Convective Weather, and Turbulence teams. The flexible and efficient MRMS software computing architecture allows for accommodation of rapid changes or additions to the NextGen objectives/requirements, while providing a straightforward research-to-operations integration platform for AWRP-funded, radar dependent, turbulence and icing solution portfolios without the system dependencies or delays associated with implementation within the WSR-88D system. The turbulence and icing solution portfolios can be implemented and configured to allow the creators to modify and improve solutions quickly, in addition to expanding the capability to utilize gap filling and international radars/networks. AWRT, via research and development funding, will continue to develop and enhance MRMS by applying:

- Data quality enhancements—e.g., calibration improvements, timely updates;
- More realistic depiction of storm structure, life cycle, and severity;
- More precise qualification of cloud microphysics aloft and on the surface; and
- Higher temporal and spatial resolution aviation centric products.

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), the NWS Climate Services Division (CSD), and more than 150 NWS regional and local offices nationwide. 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. Its 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. CPC products and services are available to government, public, and private industry users, both in this country and abroad, and are used by NWS Weather Forecast Offices (WFOs) to deliver climate services to local users. The regional and local offices also have responsibility for collecting climate data, developing locally-relevant products, and conducting local climate studies in response to user needs. Applications include the mitigation of weather-related natural disasters and uses for social and economic good in agriculture, energy, transportation, water resources, and health.

CSD provides the strategic vision for climate services at NWS, oversees the climate program including the expanded regional and local climate services programs, and serves as steward of the climate observing system. CSD develops training, education, and outreach programs that provide state-of-the-art knowledge and tools to enhance the skill set of NOAA employees and users of climate information. CSD 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. They are also responsible for the integrity and continuity of the historical climate record for their area of responsibility.

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 information 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 (IPCC) reports, the U.S. Climate Change Science Program's Synthesis and Assessment Products, and the landmark 2009 report, *Global Climate Change Impacts in the United States*. These assessment activities exemplify the kind of work and impact through which NCDC carries out its mission. Through its participation in these assessments and through dialogue with users, NCDC actively identifies the needs of NOAA data users in addressing climate change. NCDC also works to implement and operate the nation's premier surface climate observing system, the U.S. Climate Reference Network (USCRN), which operates 114 stations in the continental United States and accurately measures, with high precision, surface temperature, precipitation, soil moisture and temperature, and relative humidity. The expansion of the USCRN into Alaska has been underway since 2009 and will be completed by 2018. There are also 2 experimental stations in Hawaii.

NCDC teams developed business sector fact sheets that have been widely distributed for 12 sectors, including Agriculture, Civil Infrastructure, Coastal Hazards, Energy, Health, Insurance, Litigation, Marine and Coastal Ecosystems, National Security, Tourism, Transportation, and Water Resources. During 2010 alone, sector team members participated in over 50 sectoral meetings and hosted or co-hosted nine workshops. Through these venues, the sector teams interact with users interested in climate data and applications for their sector, in order to better understand specific sector needs for climate information. This proactive approach increases NCDC's ability to provide relevant climate data to address sector-specific needs. Sector customers such as the reinsurance and agriculture industries have noted that NCDC's data holdings and expertise enable them to make better business decisions, save money, improve their products, expand their businesses, and reduce their impact on the environment.

Release of the 2009 Bulletin of the American Meteorological Society State of the Climate Report. For the 22nd year, NOAA led the coordination, drafting, and communication of the 2010 State of the Climate Report, published in July 2011 in the *Bulletin of the American Meteorological Society*. The State of the Climate Report documents the status of the climate system and the capacity to observe it. This assessment is based upon observed conditions in more than 40 aspects of the climate system. More than 365 authors from 45 countries contributed to the 2010 edition. NCDC scientists and graphics professionals led the editorial construction and composition of the 272-page report. The report and other related materials can be found on-line at www.ncdc.noaa.gov/bams-state-of-the-climate/2010.php.

1981-2010 Climate Normals. NCDC released the 1981-2010 Climate Normals in 2011. In brief, Normals are three-decade averages of numerous climatological variables, most notably temperature and precipitation. Normals serve as a point of reference for "typical" climate conditions at a given location and are utilized in countless applications across a variety of sectors. The once-a-decade release in 2011 updated the Normals for more than 7,500 locations across the United States and added Normals data for over a thousand new stations. To prepare this release, NCDC produced hourly, daily, monthly, seasonal, and annual Normals for numerous climatological variables, including temperature, precipitation, and snowfall. Normals were also computed for derived quantities such as heating and cooling degree-days and the number of days per month above or below certain thresholds. NCDC made many improvements and additions to the scientific methodology used to calculate the 1981-2010 Normals, including improved scientific quality control and statistical techniques. Consistent with the principles of the proposed Climate Service, NCDC provided full-scale user engagement before and after releasing the Normals and incorporated new products based on stakeholder feedback.

NOAA's Climate Normals are used by numerous stakeholders. For instance, builders, insurers, and engineers use the Normals for planning and risk management. Energy companies use Normals to predict fuel demand. Farmers rely on them to help make decisions on both crop selection and planting times. Agribusinesses use Normals to monitor "departures from normal conditions" throughout the growing season and to assess past and current crop yields. Normals are also commonly seen on TV weather segments for comparisons with the day's weather conditions.

U.S. Climate Reference Network. The USCRN is a network of 114 stations developed, deployed, managed, and maintained by the NCDC in the continental United States for the express purpose of detecting the national signal of climate change. The USCRN program began fielding stations in 2001, and the vision of the program is to maintain a sustainable high-quality climate observation network that 50 years from now can, with the highest degree of confidence, answer the question: "How has the climate of the nation changed over the past 50 years?" These stations were designed with climate science in mind. Three independent measurements of temperature and precipitation are made at each station, ensuring continuity of record and maintenance of well-calibrated and highly accurate observations. The stations are placed in pristine environments expected to be free of development for many decades. Stations are monitored and maintained to high standards and are calibrated on an annual basis. In addition to measurements of surface temperature and precipitation, these stations also measure solar radiation, surface skin temperature, and surface winds.

Since 2009 the USCRN has been augmented by the implementation of triplicate measurements of soil moisture and soil temperature at five depths, as well the installation of atmospheric relative humidity sensors. Experimental stations have been located in Alaska since 2002 and in Hawaii since 2005, providing network experience in polar and tropical regions. Furthermore, as part of the most recent International Polar Year and in partnership with Roshydromet (the Russian Federation's Federal Service For Hydrometeorology and Environmental Monitoring), a USCRN station was installed in Tiksi, located in the Russian Arctic, to help address the need for reference surface climate observations in high latitude regions. Deployment of a complete 29-station USCRN network into Alaska began in 2009. While the network is managed by NOAA/NCDC, the ongoing operation and continuous improvements in the system would not be

possible without the work done in partnership with NOAA's Atmospheric Turbulence and Diffusion Division. Data from all stations, in addition to all system documentation, is available from the USCRN website at http://www.ncdc.noaa.gov/crn/.

Conversion of COOP Network Observations from Paper Records to Digital Entry. The Cooperative Observer Program (COOP) consists of more than 7,500 stations where volunteer observers typically record daily weather observations on paper forms. These data are typically received at NCDC up to 45 days after the observations are taken, following mail submission and offsite digital keying of the data. In 2010, NOAA and the Regional Climate Center Program partnered to develop a Web-based data entry and quality control system for COOP observations called WxCoder III. This interface system reduces observation network and data management expenses, removes the need for paper forms, and provides higher quality climate data in near real time. NOAA can now inject these valuable data into climate monitoring and analysis activities within 24 hours of observation. By the end of 2010, NOAA had converted nearly 50% of the COOP network to WxCoder III. Receiving this dense network of surface data in near real time provides higher quality data for climate monitoring, forecast warnings and verification, model initialization, and other public service programs. At NCDC, the data provide a reliable resource for climate monitoring and assessment of extremes up to 50 days earlier than previously used. This approach is being expanded rapidly with the goal of eliminating paper submissions entirely in the near future.

Initiation of Operational Climate Data Records. In 2010, NCDC transitioned its first three satellite-derived Climate Data Records (CDRs) from research to operationally produced and sustained climate records. The CDRs provide objective climate information derived from weather satellite data that NOAA has collected over the past 30-plus years. Satellite-based climate measurements represent the longest measurement on record with global reach and reflect a national investment of billions of dollars. For the first time, NOAA is applying improved satellite analysis methods to this historical satellite data. This process shows the underlying climate trend and variability information, thereby providing increased value from this national investment. In parallel, NCDC will extend these records by applying the same methods to present-day and future satellite measurements. The results will provide trustworthy and consistent information on how, where, and to what extent the land, oceans, atmosphere, and ice sheets are changing. The three CDRs delivered in FY 2010 include calibrated global records of Earth-reflected solar radiation, Earth-emitted thermal energy from NOAA's Polar Operational Environmental Satellite (POES) program, and Earth-emitted thermal energy from the international constellation of geosynchronous satellites. NCDC's commitment to advancing CDR development is further leveraged by its sponsorship of over twenty grants to continue to develop new CDRs, including seven new ones in FY 2010.

Development of Next-Generation Geostationary Satellite Archive and Access Requirements. The NOAA data centers, working with the Geostationary Operational Environmental Satellite-R (GOES-R) program, completed archive and access requirements that make GOES-R the first new major observing system acquisition to comply with the new NOAA Administrative Order (NAO) on management of environmental and geospatial data and information. Long-term digital information preservation is challenging, as data can only be useful when interpreted by corresponding representation information. Preserving description information, as gathered in the archive and access requirements, is essential to ensure that future generations benefit from

NOAA's multibillion dollar investment in Earth observations. The NAO captures NOAA's policy for end-to-end stewardship needs for major observing systems, while also adhering to Federal geospatial data and required records management regulations. Applying all these regulations and concepts to a fully digital archive required the application of the open archive information system reference model mapped to GEOS-R. In addition, the new NOAA procedure for scientific records appraisal and archive approval was also implemented.

Climate Database Modernization Program (Kentucky, Maryland, West Virginia, and North Carolina). 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. 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. Over the past decade, CDMP has provided increased access to volumes of digitized historical records. This has greatly improved the ability of NOAA and others to monitor, assess, forecast, and predict environmental, solar, and geophysical events and to improve climate change projections. CDMP traditionally supported dozens of data rescue projects within NOAA. The imaging and keying is done in partnership with the private sector; the amount of data rescued and keyed each year is directly related to the yearly budget process.

There are now more than 58 million images and over 15 terabytes of data available online because of CDMP efforts. 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, are being digitized through the CDMP "Forts" project and will extend climate records back to the early 1800s.

Another major data integration task, the Surface Airways Observations project, has captured 410 million observations from many Weather Bureau city offices and airports dating back to 1893. In addition, over 273,000 Atlantic, Indian, and Pacific Ocean marine observations were keyed from cursive handwritten script in British East India Company logbooks dating from 1789 to1834. These data are the most significant early collection of ocean instrumental observations in the world and contain abundant observations of pressure and temperatures. These data will add significantly to the early historical marine record and enhance global climate analysis and the marine International Comprehensive Ocean-Atmosphere Data Set (ICOADS.) Through many partnerships, the logbooks were imaged, then keyed into digital form to permanently preserve their contents and make the logs easily accessible for future generations. This collection will support regional and global climate research and reanalysis efforts dating to the late 18th century and will provide valuable clues to the earth's climate during that period. CDMP is also coordinating several international projects, such as imaging and digitizing surface data from

Central and South America and imaging and keying upper-air data from several countries in Africa.

Record Setting Year for Online Data Access. NCDC provides a wealth of scientific data online in a variety of formats for quick and convenient access. These data and products support decision making for a wide variety of users across public, private, and academic interests. During FY 2010, NCDC delivered 1,097 terabytes of data online via Web systems and services, compared to 618 terabytes in FY 2009, representing a 77% increase. This increase continues the sharp trend of growth seen over the past decade in data access via NCDC's Web resources; it also reflects enhancements made to allow customers to download much larger volumes of model, radar, and satellite data. Over 2 petabytes, equal to 2 million gigabytes, of data are now accessible from NCDC's Web site. This data growth maintains the rapid increase in the in situ, NEXRAD, satellite, and model data available online via NCDC's services. To keep up with increasing data demand, NCDC continues to implement hardware upgrades able to manage the rapidly increasing system load and vast online data resources.

Online Access for the Climate Forecast System Reanalysis (CFSR). In pursuit of understanding environmental change and impact, scientists and decision makers are increasingly seeking information that will help their communities plan and respond to climate variability and change. Uninterrupted climate observations are not available for all times or at every place on Earth, so scientists use climate models to "reanalyze" the existing data to fill in the gaps. The resulting datasets, called reanalysis data, allow for improved detection, analysis, and verification of climate variability indicators and improve scientists' abilities to determine climate variation attribution. In 2010, NCDC became the primary provider to the public of the next-generation 30-year CFSR dataset. This NCEP-developed dataset is the first major reanalysis generated in more than a decade and has met users' request for easy access to the data. Once available via NCDC, CFSR data quickly became one of the most requested online datasets in NCDC's history.

To transfer the data, NCDC worked with NCEP to establish secure means of transferring more than 200 terabytes, equal to 200,000 gigabytes, of data. The data were quality-controlled and then ingested into NCDC's information technology (IT) storage system, called the Comprehensive Large-Array data Stewardship System (CLASS), and rapidly made available to customers via the National Operational Model Archive and Distribution System (NOMADS) user access system. NCDC then used the NOMADS infrastructure to provide a user-friendly suite of tools and Web-based services to allow easy public access to the data.

Global Observing Systems Information Center. The Global Observing Systems Information Center (GOSIC) provides access to data, metadata, and information from the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS) and the Regional Observing Systems such as the GOOS Regional Alliances (GRA). The GOSIC Portal can be accessed at http://gosic.org. This system provides efficient access to data and information and unique tools for searching and accessing data, such as matrices and data registry. It 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 role expanded in FY 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 plays an important role 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. The overarching goal of the GOSIC is to provide easy access to climate datasets in support of the GCOS Essential Climate Variables (ECV); the GCOS ECV matrix was updated on the GOSIC in August 2010 to incorporate new variables that were published in the latest GCOS Implementation Plan (GCOS-138) in August 2010.

NOAA Office of Marine and Aviation Operations (OMAO)

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

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

The *Ronald H. Brown* and *Ka`imimoana* annually support the TAO array by servicing approximately 60 Autonomous Temperature Line Acquisition Systems (ATLAS) and current meter moorings in the central and eastern equatorial Pacific. The *Ronald H. Brown* works in cooperation with the Woods Hole Oceanographic Institute to conduct mooring recovery and deployment operations of the Stratus Ocean Reference Station, located under the stratocumulus clouds off Chile and Peru. The ship conducts meteorological and air-sea flux observations to document and establish the accuracy of the moored metrological observations and to observe oceanic and atmospheric variability. This region is of critical importance to climate predictability.

The *Ronald H. Brown* also conducts the Northwest Tropical Atlantic Station (NTAS) project, which investigates surface meteorological forcing and oceanographic response in a region of the tropical Atlantic Ocean with strong sea surface temperature anomalies on a decadal timescale.

These issues are addressed through the analysis of surface mooring observations from a site near 15°N, 51°W. *Ronald H. Brown* also conducts the PIRATA Northeast Extension (PNE) project, a joint project of Brazil, France, and the United States. The overarching goal is to improve knowledge and understanding of ocean-atmosphere variability in the tropical Atlantic.

United States Air Force

Air Force Weather Agency, 14th Weather Squadron

The 14th Weather Squadron (14 WS) at Asheville, North Carolina, provides centralized climatological services, produces specialized weather-impact information for DOD and allied nations, and warehouses and distributes historical atmospheric technical information. The 14 WS provides decision-enabling products, allowing DOD command authorities to anticipate environmental impacts on all aspects of military operations worldwide. The squadron produces a suite of both standard and tailored products such as the Operational Climatic Data Summaries, Engineering Weather Data, Wind Roses, and Wind Stratified Conditional Climatologies, among others, as well as providing frequency of occurrence and duration for mission limiting factors. Yet, the 14WS mission is more than just climatology; it is also forensic weather. It is about analyzing the past to predict the future. Using emerging technologies to give military planners the data needed to successfully plan and execute operations, the bottom line is to give warfighters the environmental information when, where, and how it is needed to prosecute military operations.

The 14 WS enhances the combat capability of the United States by delivering timely, accurate, and reliable environmental situational awareness worldwide to the USAF, the Army, Unified Combatant Commands, the Intelligence Community, and DOD. The 14 WS also collaborates with NCDC and other national climatic centers of expertise worldwide. Collocation with the NCDC in Asheville allows for data exchange as well as joint collaboration in areas such as data quality techniques, product development, and technology exploitation to facilitate both organizations' missions.

Long range outlook products and other services relate to time periods from a month to six months in the future, including seasonal forecasts and hazard assessments. The 14 WS produces 6-month long range narrative-form outlooks derived by using statistical methods, with an ensemble of Global Climate Model forecasts, considering the El Nino–Southern Oscillation (ENSO), North Atlantic Oscillation, Southern Annular Mode, etc. In the area of climatology, Air Force Weather is developing a 6-month forecast capability by leveraging research conducted by Air Force and Navy officers at the Naval Postgraduate School and other national and international resources (including climatology work by NATO allies), as well as advances in understanding teleconnections (i.e., ENSO, North Atlantic Oscillation, Southern Annular Mode), with a goal of providing planners with a risk management tool to positively impact operations.

To support Air Force training and exercises, the 14 WS is involved in several areas such as exploiting modeling and simulation technologies, including Advanced Climate Modeling and Environmental Simulations, to produce modeled climate statistics and gridded climatologies, and he Environmental Scenario Generator to produce simulated environmental scenarios. The 14 WS also oversees the 250,000 documents archived in Air Force Weather's Technical Library.

United States Navy

The earth's climate is changing, and the most rapid changes are occurring in the Arctic. Because the Arctic is primarily a maritime environment, the Navy must consider the changing Arctic in developing future policy, strategy, force structure, and investments for environmental assessment and prediction. These investments include research for and development of a next-generation environmental prediction capability applicable to the Arctic. The Oceanographer of the Navy serves as Director of Task Force Climate Change (TFCC) and develops comprehensive approaches regarding the Arctic and global climate change. 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, *Joint Vision 2020*, *Sea Power 21*, *a 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 the 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.

Rear Adm. David Titley, second from left, Director of the U.S. Navy Task Force Climate Change (TFCC), leads an onsite discussion of climate in the Arctic Ocean and its possible impacts on the Navy. (http://www.navy.mil/view_galleries.asp)

United States Geological Survey (USGS)

The USGS is both a provider of and user of climate-related services, but the balance between these two activities is quite different from that of NOAA. The USGS provides climate data and models, like NOAA, that can be used by resource managers and policy makers to anticipate and adapt to climate change. The USGS climate and land use change science program, however, also has a strong emphasis on understanding relationships between climate change and hydrological, geologic, and biological processes.

USGS has expertise and numerous research projects and products that describe long-term changes in the Earth's climate. The climatic datasets developed by the USGS are based primarily on Earth surface and subsurface records, in contrast to the atmospheric records developed by NOAA. USGS climatic datasets are derived from ice sheets, glaciers, and permafrost; tree rings, landscape-scale phenology, and other biological data; and rock, sediments, and other paleodeposits, in addition to modern meteorologic, hydrologic, and remote sensing instrumentation. The USGS manages an international ice core facility in Denver, Colorado, and has numerous studies devoted to understanding the natural variability of climate and its attendant changes and to providing context for the development of mitigation and adaptation strategies. The Ice Core Laboratory is just one example of the services provided by the USGS to the scientific community engaged in understanding the Earth's climate history. Another good example of the climate services provided by the USGS is the Department of the Interior's network of regional Climate Science Centers. These centers are staffed by the USGS and have research and information delivery capabilities designed to respond to the needs of natural resource managers.

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 the 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 WMO and the United Nations Environment Program (UNEP), held its first session in 1988. This organization serves as an intergovernmental 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).

In addition to its primary role in the organizations and events listed above, DOS is active in several relevant Federal 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

NOAA/NESDIS National Climatic Data Center

Supporting Federal Climate Assessment Services. NOAA established a Technical Support Unit at NCDC to provide critical information and capabilities to support the National Climate Assessment (NCA), being run by the U.S. Global Change Research Program (USGCRP). The NCA is conducted under the auspices of the Global Change Research Act of 1990, which requires a report to the President and Congress that evaluates, integrates, and interprets the findings of the USGCRP every four years. With the next Assessment due in 2013, the agencies participating in the USGCRP seek not only to deliver the assessment report, but also to establish an ongoing, sustainable assessment process, which will require a wide network of interagency and external support. A key component of this ongoing process will be an interactive Web presence for NCA queries at http://globalchange.gov/what-we-do/assessment. The NCA aims to incorporate advances in the understanding of climate science into larger social, ecological, and policy system understanding and with this, to provide integrated analyses of impacts and vulnerability. The NCA will help evaluate the effectiveness of mitigation and adaptation activities in the face of a changing climate.

Assuring the Reliability of the U.S. Surface Temperature Record. In January 2010, a paper entitled "On the reliability of the U.S. Surface Temperature Record" was published in the peer-reviewed *Journal of Geophysical Research—Atmospheres*. Conducted by NCDC scientists Dr. Matthew Menne, Claude Williams, and Dr. Michael Palecki, this important study addressed the impact of poor siting conditions at stations in the U.S. Historical Climatology Network (USHCN) Cooperative Observation (COOP) network. NCDC needed to assess if and how the site conditions, such as locations next to buildings or heat sources, impacted the long-term temperature record. Through their study, Menne, Williams, and Palecki found that continental U.S. temperature trends are not inflated due to poor exposure. Results indicated that there is a mean bias associated with poor exposure sites relative to good exposure sites; however, this bias is consistent with previously documented changes associated with the widespread conversion to electronic sensors in the USHCN COOP during the past 25 years. Homogeneity adjustments applied to USHCN Version 2 data were found to account for the impact of instrument and siting changes. The adjusted USHCN COOP temperatures were also found to be extremely well aligned with measurements from the U.S. Climate Reference Network, whose instruments and exposure characteristics meet the highest standards for climate monitoring. This work verifies

the validity of analyses included in the 2009 report, *Global Climate Change Impacts in the United States*. It also shows that problems with station siting at USHCN COOP sites have been accurately addressed through application of the Menne and Williams Pairwise Homogeneity Adjustment algorithm and ensures the integrity of the U.S. surface temperature record.

Tropospheric Temperature Trends. Scientists at NOAA, the NOAA-funded Cooperative Institute for Climate and Satellites (CICS), the United Kingdom Meteorological Office, and the University of Reading in the United Kingdom contributed to the paper, "Tropospheric Temperature Trends: History of an Ongoing Controversy," a review of four decades of data and scientific papers. The paper was published in November 2010 by *Wiley Interdisciplinary Reviews: Climate Change*, a peer-reviewed journal. According to this extensive review of the scientific literature, the science conclusively states that the troposphere, the lower part of the atmosphere closest to the Earth, is warming and that this warming is broadly consistent with both theoretical expectations and climate models. In the 1990s, some observations did not show the troposphere, particularly in the tropics, to be warming even though surface temperatures were rapidly warming. This lack of tropospheric warming was used by some to question both the reality of the surface warming trend and the reliability of climate models as tools. In extensively reviewing the relevant scientific analyses—195 cited papers, model results, and atmospheric datasets—the paper states that the body of science shows there is no longer evidence for a fundamental discrepancy and that the troposphere is indeed warming.

Development of GHCN-M Version 3 Monthly Mean Temperature Dataset. Since the early 1990s the Global Historical Climatology Network-Monthly (GHCN-M) dataset has been an internationally recognized source of data for the study of observed variability and change in land surface temperature. It provides monthly mean temperature data for 7,280 stations from 226 countries and territories, ongoing monthly updates of more than 2,000 stations to support monitoring of current and evolving climate conditions, and homogeneity adjustments to remove nonclimatic influences that can bias the observed temperature record. The release of Version 3 Monthly Mean Temperature Data marks the first major revision to this dataset in over ten years. It introduces a number of improvements and changes that include consolidating "duplicate" series, updating records from recent decades, and the use of new approaches to homogenization and quality assurance. NCDC developed new quality control methodologies, applied a new homogeneity adjustment algorithm to extend and improve bias corrections to in situ stations on every continent, developed a new update system to ensure all updates to source datasets can be incorporated immediately, established a version control and data provenance system to improve the traceability of data, and made other changes in response to user requests to broaden the use of this dataset to a wider community. This new version provides a global dataset of higher quality for diverse user communities. The data are easier to access, easier to understand, and more complete.

Global Tropical Cyclone Database Development. In FY 2009, NOAA unveiled the International Best Track Archive for Climate Stewardship (IBTrACS) under the auspices of the World Data Center for Meteorology at NCDC. IBTrACS 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 (RSMCs) 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; and
- Checks the quality of storm inventories, positions, pressures, and wind speeds, passing the information on to the user.

To ensure that the procedures and algorithms that IBTrACS employs meet the requirements of the international IBTrACS community and to coordinate with the various RSMCs and other international data centers involved in tropical cyclone best tracks, the IBTrACS team has held two very successful international workshops, one in 2009 in Asheville, North Carolina, the second in 2011 in Honolulu, Hawaii.

Improving Hurricane Forecasts in the Atlantic. Atlantic hurricane forecasts from NOAA's National Hurricane Center (NHC) include information on track and storm intensity. Over the past twenty years, errors in track have been cut in half, but intensity forecasting is still a key research area. Dr. Jim Kossin of NCDC is dedicated to improving intensity forecasts with the development of two experimental models: one for predicting hurricane eyewall replacement cycles (ERC) and one aimed at understanding rapid intensity changes. In 2010, the ERC model became fully operational during hurricane season and has the potential to improve not only forecasts but also storm surge predictions. Both projects are part of the Joint Hurricane Testbed research-to-operations project.

Paleoclimatology Reconstructions Network. NOAA Paleoclimatology studies of drought records in Asia have led to extending the record farther back in time using tree ring records. Natural variability in monsoon rainfall, including droughts and persistent heavy rainfall called "pluvials," affects billions of people and entire economies across Asia. Tree ring data provides a much longer history of drought variations than the historical record does, bringing into sharper focus the decadal variability and revealing such extreme anomalies as "megadroughts," or droughts of longer duration that were more severe than anything observed in the short instrumental record. Long climate records that resolve the natural variability are essential to improved prediction of the Asian summer monsoon. NCDC archived the Monsoon Area Drought Atlas (MADA) data and provides maps, visualizations, and data for droughts that occurred centuries ago. Via MADA, NCDC provides a gridded reconstruction of the Palmer Drought Severity Index, derived from 327 tree ring chronologies and extending back to 1300 AD. In addition to providing data files, NOAA also provides maps and interactive visualizations of major droughts and pluvials across monsoon Asia, such as the Ming Dynasty Drought (1638–1641) and the East India Drought (1790, 1792–1796).

Continued Growth of Cooperative Institute for Climate and Satellites North Carolina (CICS-NC). Since the inauguration of CICS-NC on July 1, 2009, the CICS-NC team has grown to

comprise 20 researchers (14 PhD and 6 MA/MS) supporting the NCDC mission with a focus on enhancing the collective interdisciplinary understanding of the state and evolution of the full Earth system. Focusing on seven research areas, from Climate Data Records to National/Regional Assessments, these researchers have published nearly 20 peer-reviewed papers since the institute's inception. Over the past year, CICS-NC scientists led contributions to the IPCC Fifth Assessment Report, edited a chapter of the authoritative 2009 *State of the Climat*e annual report, and engaged in international management of the Global Climate Observing System Reference Observing Network and the recently instigated International Surface Temperature Initiative. CICS-NC scientists have presented at over 10 conferences, with nearly 20 presentations on the topics of climate research and applications, satellite and observation monitoring, and climate modeling. CICS-NC is also spearheading outreach activities that enhance the value of science, innovation, research, and education. In 2010, CICS-NC established the "CICS Cluster" of 340 nodes used by researchers for collaborative development and software validation. CICS-NC has also initiated the planning for the "Summer Institute on Climate Adaptation" to be held in Asheville in June 2012.

International Drought Workshops. Contributors to the North American Drought Monitor (NADM) have increasingly recognized that global-scale drought monitoring and mitigation and a drought response system would benefit all nations affected by drought, especially those in semiarid regions. In April 2010, NCDC scientists led three concurrent workshops aimed at identifying and addressing the unique needs of the international drought monitoring community. These three concurrent workshops in Asheville focused on better data sharing and information design. The result was improved bilateral drought monitoring arrangements between the United States and both Canada and Mexico, as well as a new vision for coordinating global drought monitoring efforts. The workshops also led to progress on creating drought early warning systems and regional drought monitoring centers in parts of many continents. All workshops noted the challenge of inadequate data and indices for detecting drought, which is a continuing area of international collaboration.

USCRN Soil Sensor and Relative Humidity Sensor Installation. Begun in FY 2009 and completed at the end of FY 2011, NCDC, in partnership with NOAA's Atmospheric Turbulence and Diffusion Division (ATDD) in Oak Ridge, Tennessee, completed the installation of a triplicate set of soil moisture and temperature sensors at 5 standard soil depths from 5 to 100 cm deep, in addition to relative humidity sensors, at all 114 of the USCRN stations in the conterminous United States.

Soil temperature and moisture (as well as relative humidity) are critical Essential Climate Variables (as defined by GCOS[1]) for monitoring long-term drought and climate change. Given that the primary mission of the USCRN is to be able to detect and confirm long-term climate change, the implementation of these new soil and relative humidity sensors will vastly improve the network's capability to fulfill this mission.

NOAA's National Integrated Drought Information System (NIDIS) recognized the need for and value of such a project and has provided the necessary support and resources to not only ensure project completion but also to support continued operations and maintenance and continuous

[1] See http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf

improvement. This support also enables ongoing science work to continue in a sustainable manner required by long-term climate observing systems. NCDC worked with ATDD to lay out a 3-year plan from 2009 through 2011 for installing these new sensors in a manner that would enhance the USCRN while not interrupting operations at network sites. In addition, NCDC worked to ensure that data from the new sensors were made immediately available via both the USCRN website and the NIDIS data portal[2] (the Federal government's overall "Data.Gov" portal site). Since the installation of these new sensors requires the development of appropriate science products, work was begun in parallel to ensure that the maximum benefit from this project is achieved.

The soil and relative humidity monitoring that is facilitated by this project is of key importance to a number of sectors of the economy. The benefits from the data span many science disciplines and technical applications including hydrology, climate, the Earth's carbon cycle, and applications of value to the meteorological, environmental, and ecology communities. Economic sectors including agriculture and water resource management will be better able to serve their customers, on whom millions of Americans depend. Having these data available on a timely basis will be a great addition to the USCRN climate datastream. Data from USCRN soil sensors (at least down to the 5 cm level) will be of critical importance to the calibration and validation work (e.g., establishing ground truth) required by NASA's Soil Moisture Active-Passive (SMAP) mission, which is scheduled for launch in the 2014 timeframe. [3]

NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory (AOML)

In an effort to better understand and forecast climate, AOML has been deploying a global array of profiling floats since 2000. The broad-scale global array of temperature and salinity profiling floats, known as Argo, has already grown to become 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 transmitting 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 World Climate Research Programme's (WCRP) 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, GCOS, and GOOS.

[2] See http://www.drought.gov/portal/server.pt/community/drought_gov/202/crn_soil_data?qid=01652419&rank=6
[3] See http://smap.jpl.nasa.gov/

NOAA/OAR Earth System Research Laboratory (ESRL)

The ESRL Chemical Sciences Division (CSD) climate services research provides an improved predictive capability through a better understanding of the connections between emissions, atmospheric composition, and Earth's climate system. Research is focused on addressing two of the greatest uncertainties in current climate models: water vapor and aerosols (airborne fine particles), in addition to ongoing work on non-CO_2 greenhouse gases. Work is underway to improve the measurement of water vapor and understanding its atmospheric distribution, with a focus on the upper atmosphere, where the water vapor abundance is a key factor in determining the amount of radiation lost to space and the heating of the lower atmosphere and Earth surface. A better quantification of water vapor and its distribution in this part of the atmosphere is needed to properly account for past changes in the Earth's climate and reliably predict/project future changes. The IPCC has identified the role of atmospheric aerosols in climate change as the single greatest uncertainty in our ability to predict changes to the climate system. Research is addressing key uncertainties related to both absorbing (e.g., black carbon) aerosols that warm the atmosphere, and scattering (e.g., sulfate) aerosols that cool the atmosphere, in particular their emission/formation and evolution in the atmosphere, with a particular emphasis on quantifying the influence of aerosols on cloud formation, extent, and optical properties (Earth's radiation balance) as well as on precipitation. CSD also places a high priority on communicating the results of its research in decision-support information products to underpin national and international decisionmaking. CSD's contributions include leadership and extensive participation in state-of-understanding assessments on climate, such as the IPCC assessments and special reports, synthesis and assessment reports of the USGCRP, and the Montreal Protocol assessment on the ozone layer.

The ESRL Global Monitoring Division (GMD) conducts sustained observations and research related to global distributions, trends, sources and sinks of atmospheric constituents that are capable of forcing change in Earth's climate. This research will advance climate projections and provide scientific policy-relevant, decision-support information to enhance society's ability to plan and respond.

To slow the rate of anthropogenic-induced climate change in the 21st century and to minimize its eventual magnitude, societies will need to manage the climate forcing factors that are directly influenced by human activities, in particular greenhouse gas and aerosol emissions. For effective management of these species, a solid scientific understanding of their natural cycles and the processes that influence those cycles is necessary. Atmospheric measurements are the touchstone of theories or models describing these cycles. Providing a sound basis for important societal decisions requires a global effort, one that involves studying numerous gases, particles, and atmospheric radiation on appropriately designed spatial and temporal scales.

The combined effects of climate forcing lead ultimately to alteration of the earth's radiation budget. Broadband irradiance, measured continuously at numerous locations around the globe, provides benchmarks of climatic processes. Forced changes in irradiance are not only affected by changing concentrations of constituents or other external sources but also by changes in water vapor and clouds. The longest continuous record of solar radiation at the surface (55 years and counting) comes from Mauna Loa Observatory measurements. The 31-year record of increasing

stratospheric water vapor concentrations collected by balloon-borne instruments above Boulder, Colorado, is the sole such long-term record in existence.

The Mauna Loa Observatory, Hawaii, record of continuously increasing atmospheric carbon dioxide concentrations was begun in 1956 and continues today, the longest such record on Earth. NOAA/GMD measures nitrous oxide (N_2O), chlorofluorocarbons (CFCs), ozone (O_3), methane (CH_4), carbon monoxide (CO), hydrochlorofluorocarbons (HCFCs), methyl halides, and sulfur hexafluoride (SF_6) at up to 65 sites around the globe. Measurements of carbon isotopic ratios of CO_2 and CH_4 allow for understanding relative fossil fuel and natural sources for these gases.

In addition to monitoring aerosol properties at remote Atmospheric Baseline Observatories, in response to the finding that anthropogenic aerosols create a significant perturbation in the earth's radiative balance on regional scales, ESRL/GMD expanded its aerosol research program (1992) to include continuous aerosol monitoring stations in regions where significant aerosol forcing was expected. The goals of this regional-scale monitoring program are to characterize the means, variabilities, and trends of climate-forcing properties of different types of aerosols and to understand the factors that control these properties. An important aspect of this sampling strategy is linking chemical measurements to physical measurements. ESRL/GMD's aerosol measurements also provide ground-truth data for satellite measurements and inputs for global models.

United States Geological Survey

Water Resources Monitoring. The effects of warming temperatures on water resources are among the most certain and costly consequences of climate change in some regions of the United States, and water resources information should be an important component of (or closely linked with) a new national climate services program. The USGS is the nation’s water resource monitoring agency, with one or more offices in every State and a National stream and groundwater monitoring network that supports water management efforts at State and local levels, as well as vast western water resources managed by two other Department of the Interior bureaus: the Bureau of Reclamation and the Bureau of Land Management (BLM). The USGS has a long-established hydroclimatology research program and is the primary Federal science agency for water resource information. The USGS monitors the quantity and quality of water in the Nation's rivers and aquifers and develops tools to improve the application of hydrologic information, including the effects of a changing climate. This broad, diverse mission cannot be accomplished effectively without the contributions of the Cooperative Water Program with the 50 states. For more than 100 years, the Cooperative Program has been a highly successful cost-sharing partnership between the USGS and water-resource agencies at the State, local, and Tribal Nation levels.

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 United States. This program includes research on the effects of atmospheric and climatic variables on watershed processes. There are also a number of ongoing studies to characterize trends in hydrologic data and to relate these trends to climatic variables. Researchers

are also using global and regional climate models to enhance understanding of the potential effects of climate change and climate variability on U.S. land and water resources.

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 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 archive of ongoing 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.

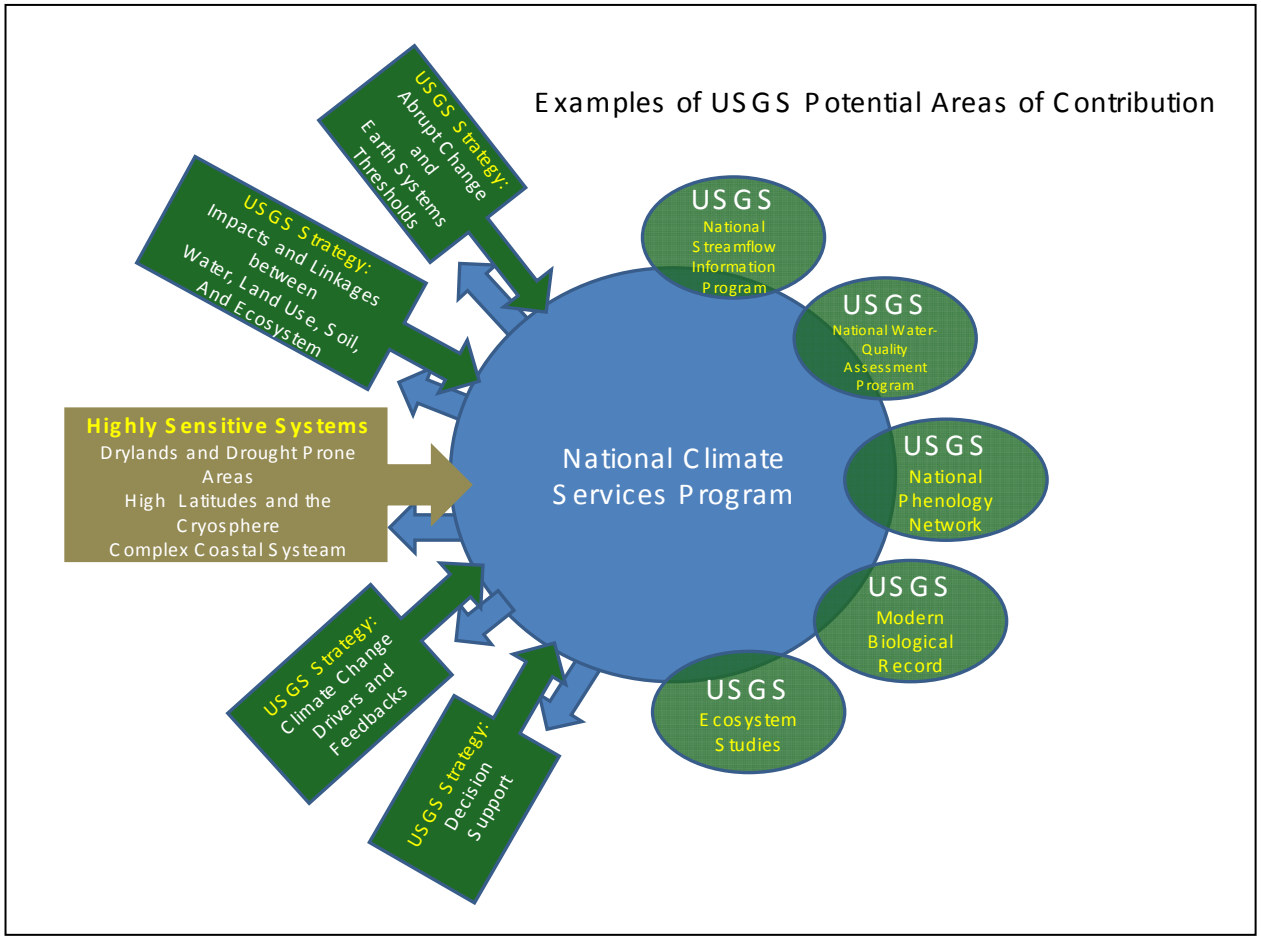
Snow and Ice Studies. The USGS, in cooperation with BLM, is using a variety of remote sensing data to monitor the rapid wastage of the piedmont lobe of Bering Glacier, Alaska. Landsat, Radarsat, ICESat, and Ikonos observations show that Bering Glacier is retreating rapidly and thinning in an accelerating 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.

Geological Investigations. The USGS has traditionally led the USGCRP projects devoted to understanding cycles in the Earth's climate, abrupt climate change, ecological thresholds, and climate change in polar regions. These cycles are generally underrepresented in the available data from meteorological records. By combining paleoclimatic and instrumental data, USGS scientists have contributed substantially to understanding how past and current changes in the Earth's climate affect water, land, and biological resources.

Biological Indicators of Climatic Trends. The National Phenology Network, Breeding Bird Surveys, and Amphibian Research and Monitoring Initiative are examples of USGS biological science programs that provide national coverage and uniform protocols for reporting the occurrence of biological events that can augment analyses of changes in the physical climate system.

USGS Role in National Climate Services. The USGS has several additional programs and projects that would directly support and complement an interagency national climate services program. The USGS develops global and regional climate models and contributes to international programs of model development (e.g., the WCRP and phase 3 of the Coupled Model Intercomparison Project [CMIP3]). It targets model applications to investigate past, present, and future climate change (mean and variability) and how those changes influence and are influenced by surface systems. Applications include surface and subsurface hydrology, terrestrial and marine ecosystems, glaciology, and wildland fire research. USGS model simulations are often targeted to specific natural resource response and management questions rather than production runs for activities such as the IPCC assessments. Its modeling activities are flexible, with quickly implemented experimental designs that are often modified through an iterative process involving cross-disciplinary researchers.

The figure below depicts some of the potential areas of USGS collaboration and support toward a coordinated interagency national climate services program.



National Aeronautics and Space Administration

Science Mission Directorate, Earth Science Division

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 competitive peer-reviewed opportunities offered through Research Opportunities in Space and Earth Science (ROSES) announcements.

Climate services will require development and delivery of data, tools, and information that are science-based, user-responsive, understandable, credible, and relevant to decisionmakers. They will depend on an integrated system that links essential observations, data, research and analysis, and predictions to the iterative development of service-oriented information for societal benefits.

NASA's climate research program is unique because it 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 the data products resulting from these missions; research to increase basic process knowledge; incorporation of observations and research 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.

NASA is the largest funding contributor to the 13-agency USGCRP and provides the bulk of the global observations and research by the USGCRP. NASA delivers much of the observations and research that forms the basis for international scientific assessments of climate change and other subjects such as ozone. In FY 2012, NASA will chair the Committee on Earth Observation Satellites Strategic Implementation Team (CEOS SIT).

Satellite Missions. *Satellites provide critical climate change measurements via global coverage, f*requent 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 and 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.

NASA has 14 on-orbit satellite missions: ACRIMSAT, Aqua, Aquarius/SAC-D, Aura, CALIPSO, Cloudsat, EO-1, GRACE Jason-1, Landsat-7, OSTM, SORCE, Terra, and TRMM. Table 1 lists the climate services themes supported by these missions. On March 4, 2011, NASA's Glory satellite did not reach orbit altitude due to malfunction of the launch vehicle. On June 9, 2011, the Aquarius sea surface salinity instrument was launched on Argentina's SAC-D satellite.

Table 1. Correlation of NASA Earth Science Division operating satellite missions with OFCM themes of climate services.

Satellite	Launch Date	Climate Services Theme
ACRIMSAT	Dec 1999	Climate variability and change
Aqua	May 2002	Atmospheric composition; carbon cycle; climate variability and change; water cycle
Aquarius	Jun 2011	Climate variability and change; water cycle
Aura	Jul 2004	Atmospheric composition
CALIPSO	Apr 2006	Atmospheric composition; water cycle
CloudSat	Apr 2006	Climate variability and change; water cycle
EO-1	Nov 2000	Carbon cycle
GRACE	Mar 2002	Climate variability and change; water cycle
Jason-1	Dec 2001	Climate variability and change; water cycle
Landsat-7	Apr 1999	Carbon cycle
OSTM	Jun 2008	Climate variability and change; water cycle
SORCE	Jan 2003	Climate variability and change
Terra	Dec 1999	Atmospheric composition; carbon cycle; climate variability and change; water cycle
TRMM		Nov 1997 Climate variability and change; water cycle

A daunting challenge in supporting 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 now placed at a lower orbit, 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 processes related to cirrus cloud formation in large-scale models.

NASA has 6 satellite missions in development (Table 2) for launch from 2011 to 2015. NPP, LDCM, and GPM Core are foundational missions, which the Decadal Survey by the National Research Council[4] assumed would be precursors to Decadal Survey missions. SMAP and

[4] National Research Council (2007) *Earth Science and Applications From Space: National Imperatives for the Next Decade and Beyond*, 428 pp.

ICESat-2 are Tier-I Decadal Survey missions. OCO-2 replaces the original OCO, which did not reach orbit in February 2009 due to a launch vehicle failure.

The President's FY 2012 Budget advances key elements of the program established in NASA's 2010 Climate Initiative. The budget enables launch of the first two Tier 1 Decadal Survey missions, SMAP and ICESat-2, in 2014 and 2016, respectively, and extends the Venture-class

Table 2. Correlation of NASA Earth Science Division missions in development with OFCM themes of climate services.

Satellite	Planned Launch	Theme
NPP	Oct 2011	Climate variability and change
OCO-2	Feb 2013	Carbon Cycle
LDCM	Jun 2013	Carbon cycle
GPM	Jul 2013	Climate variability and change; water cycle
SMAP	2014	Climate variability and change; water cycle
ICESat-2	2016	Climate variability and change; water cycle

competitive program with annual solicitations for facility-class instruments and alternating biennial solicitations for small missions and airborne investigations. The budget supports continued development of options for the Decadal Survey Tier-1 DESDynI radar satellite. Two climate-focused Tier-2 Decadal Survey missions, SWOT for insight into the movement and distribution of Earth surface waters including both freshwater and oceans and ASCENDS for atmospheric column CO_2 abundance, have been initiated for launch in 2019-2020. Recognizing the broad societal and policy impact of NASA's Earth observations, NASA will continue to develop the OCO-2 mission for launch in 2013, begin building the OCO-3 as a mission of opportunity, and initiate missions to continue climate time series. NASA will refurbish the SAGE-III instrument for flight on the International Space Station (ISS) as early as 2014, develop the PACE mission for ocean color, and initiate a GRACE-FO gap-filler mission for launch in 2016 to continue the measurements, including observations of changes in terrestrial water storage and ice mass, now made by the aging GRACE mission.

The following activities will be undertaken or accomplished in FY 2012.

- The 2011 Senior Review, conducted at 2-year intervals, concluded that all 12 on-orbit satellite missions in extended operations (Aqua, Aura, CALIPSO, CloudSat, EO-1, GRACE, Jason-1, OSTM, QuikSCAT, SORCE, Terra and TRMM) would receive funding for continued operations and core-data products in FY 2012 and FY 2013 (either augmented, reduced, or no change) because of the missions' contributions to science and the national interest and their cost-effectiveness in terms of technical performance and cost of mission extension.
- GPM will complete its System Integration Review (SIR) and Key Decision Point (KDP)-D.
- NPP will complete all pre-launch activities, launch, and conduct the initial on-orbit checkout and instrument calibration and validation.

- LDCM will complete the Flight Operations Review (FOR) and the integration and testing of the observatory.
- SMAP will complete mission Critical Design Review.
- ICESat-2 will complete KDP-B and initiate the spacecraft contract.
- The GRACE-FO continuity mission will complete a pre-formulation phase and enter into Phase A formulation.
- DESDynI will complete its pre-formulation pre-Phase A analysis of developmental options.
- CLARREO will continue its pre-Phase A studies.
- SAGE-III will complete its ISS accommodation assessment and initial refurbishment.
- SWOT and ASCENDS will complete their pre-Phase A activities and enter into formulation with the completion of KDP-A for each
- Aquarius/SAC-D will complete its on-orbit checkout and begin sustained observations.
- OCO-2 spacecraft will be delivered and complete SIR.
- Release of the first Earth Venture (EV) instrument Announcement of Opportunity (AO) for a facility-class instrument and selection of winning proposal(s).
- Continuation of EV-1 sustained airborne science campaigns.
- Selection of winning EV-2 proposals.
- Selection of Advancing Collaborative Connections for Earth System Science (ACCESS) projects from proposals submitted in response to the FY 2011 ROSES (ROSES-11) solicitation.
- Update Earth Observing System Data and Information System (EOSDIS) to receive OCO-2, GPM, and Decadal Survey mission data.

NASA Science Research

NASA will continue implementation of the airborne IceBridge campaign to acquire essential polar ice data during the gap between the ICESat and ICESat-2 missions. This activity, focusing on changes in Greenland and Arctic ice, will continue in FY 2012 and each year until ICESat-2's launch in 2016.

The research program develops and tests experimental techniques and algorithms that contribute to future satellite missions. The FY 2012 President's Budget enhances support for interdisciplinary science and NASA observational- and model-based contributions to national and international climate assessments, e.g., the US National Climate Assessment and the IPCC Fifth Assessment Report.

The FY 2012 President's Budget enhances support for interdisciplinary science; for observational and model-based contributions to national and international climate assessments; for work towards a Carbon Monitoring System (CMS), specifically the development of two pilot projects; and for a scoping study and increased investment in scientific computing and space

geodesy. The two CMS pilot products are a terrestrial biomass pilot product and an integrated emission and uptake flux pilot product. For the former, NASA will demonstrate how well biomass can be quantified with high quality remotely sensed data from aircraft at selected sites representative of U.S. forest types and conditions. The pilot flux product will combine satellite data with modeled atmospheric transport to link the observations with surface exchange processes to estimate the atmosphere-biosphere CO_2 exchange processes.

The following research activities will be undertaken or accomplished in FY 2012:

- Release request for proposals through ROSES
- Increase supercomputing cycles
- Continue IceBridge campaigns
- Complete Impacts of Climate on Ecosystems and Chemistry of the Arctic Pacific Environment (ICESCAPE) campaign
- Select airborne mission teams for Mid-latitude Airborne Cirrus Properties Experiment (MACPEX)
- Increase the number of science data products delivered to EOSDIS

Department of Energy, Office of Science

DOE's Climate and Environmental Sciences Division (CESD) within the Office of Science focuses on a predictive, systems-level understanding of the fundamental science associated with climate change and DOE's environmental challenges; both key to support 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. As discussed next, CESD supports three research activities and two national scientific user facilities:

Atmospheric System Research (ASR)

The ASR activity 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. Research from the ASR program results in improved physical formulations leading to state-of-the-art science related to clouds, aerosols, radiation, and precipitation. The program is geared to observe and advance understanding of the atmospheric system in a holistic, comprehensive fashion that addresses the full range of interrelated climatic processes. The anticipated end result is that climate models will have reduced uncertainty and improved climate simulation capability so that climate models can be used with increased confidence in decision- and policy making.

Climate and Earth System Modeling

Climate and Earth System Modeling in CESD focuses on development, evaluation, and use of Regional and Global Climate Modeling (RGCM), the development of Earth System Models

(ESM), and Integrated Assessment Models to determine the impacts and possible mitigation, of climate change.

Achieving greater detail about uncertainty and future variability of the earth climate system is critical for decision-makers. There is a need to ascertain shifts in major modes of climate variability and climate extremes, to detect and attribute regional manifestations of climate change, and to conduct ever more thorough model validation. All these goals of the RGCM program remain significant challenges. This program also provides support for national and international climate modeling research and assessments. An understanding of the model biases seamlessly feeds back to the ESM program.

RGCM activities are organized into several distinct but coordinated components:

- The **Program for Climate Model Diagnosis and Intercomparison** (PCMDI) develops improved methods and tools for the diagnosis and intercomparison of climate and Earth system models. It provides major facilities for archiving climate model output, including frequently analyzed variables such as those used for the IPCC Assessment Reports. PCMDI makes such model output readily accessible to the climate modeling community.
- The **Climate, Ocean and Sea Ice Modeling Project** (COSIM) continues to develop the ocean model POP (Parallel Ocean Program), its hybrid-coordinate successor (HYPOP), and a sea ice model (CICE). COSIM is also developing a new Community Ice Sheet Model (CISM), designed for use at high spatial resolutions and at high latitudes. The scientific thrust of this work is to understand the role of oceans and ice in climate change, including (1) future sea-level rise caused by thermal expansion of the ocean and by melting of land ice; (2) stability of the high-latitude ocean thermohaline circulation; and (3) the unique high-latitude marine and ice ecosystems that reside along the ice edge and how they respond to changes in sea ice extent, including consequences for carbon and sulfur uptake and exchange.
- Multi-century simulations using the Climate Change Simulation Model (CCSM) are conducted by the DOE Climate Change Project at the National Center for Atmospheric Research (NCAR). Analysis of CCSM simulations provides insights into how natural and anthropogenic forcings affect the coupled climate system.

Research from the ESM program results in improved state-of-the-science dynamically coupled models for understanding future variability and predictability of the climate system. Significant scientific challenges need to be addressed, such as future changes in major modes of climate variability, climate extremes in a changing climate, detecting and attributing the regional manifestations of climate change, and carbon-cycle interactions with climate. Improved climate information at high spatial and temporal resolution is of immense significance to society and decision-makers.

Climate change is real, its effects are more immediate and profound than previously anticipated, and old questions (are humans the cause?) are yielding to new ones: What are the impacts? Who and what will be most vulnerable? What can we do about it, and how can we prepare? Against this backdrop, and with an eye toward: (1) regional and local scale insights; (2) quantitative predictions at the decadal, annual, and even shorter time scales; (3) policy-making, planning and

decision-support tools; (4) impacts, adaptation, and vulnerability studies; and (5) highly integrated analyses spanning energy, environment, and economic security, new or vastly improved Integrated Assessment Models will inform some of the most significant U.S. energy and other infrastructure decisions and investments of this century. These models shape our fundamental understanding of climate change: the drivers of climate change; its pace and consequences; the implications and role for energy systems of the future; changes in availability of natural resources, food, and water; and shifts in global economies, vulnerabilities and overall national security.

Environmental System Science

The Environmental System Science activity in CESD seeks to advance a robust predictive understanding of energy-derived byproducts in terrestrial ecosystems extending from the bedrock to the top of the canopy and from molecular to global scales. This activity focuses on understanding the role of terrestrial ecosystems in a changing climate[5] and the role of subsurface biogeochemical processes in the fate and transport of heavy metal and radionuclide contaminants in subsurface systems.[6] DOE is responsible for what has been described as the largest, most complex, and diverse collection of environmental remediation challenges in the nation. While some of the problems are tractable and require only time and money to resolve, a large fraction of them cannot be resolved with existing knowledge and technology. The need for solutions to these challenging environmental remediation problems drives the Environmental System Science program.

Future climatic changes will almost certainly affect many important organisms and processes in terrestrial ecosystems, and these ecosystems provide society with a host of essential goods and services. The Environmental System Science program's research is directed at obtaining and then disseminating scientific knowledge of the most important effects of climatic change on ecosystems so that society can understand the ecological implications of climatic change and then plan for those changes. While the program focuses on U.S. terrestrial ecosystems, much of the knowledge gained has global applicability.

The terrestrial biosphere is a major factor influencing the transport and concentration of atmospheric greenhouse gases including carbon dioxide. Current limitations of our understanding of carbon cycling through terrestrial ecosystems account for significant uncertainties in projections of future climate scenarios. This program seeks to identify critical carbon cycle pathways, provide quantitative explanations for those pathways and integrate the resulting process understanding into coupled carbon-climate models.

CESD National Scientific User Facilities

Two scientific user facilities—the Atmospheric Radiation Measurement Climate Research Facility (ARM) and the Environmental Molecular Sciences Laboratory (EMSL)—provide the scientific community with technical capabilities, scientific expertise, and unique information to facilitate science in areas of importance to DOE's mission. The ARM is a multiplatform facility that supports research for addressing the major uncertainties of climate models: clouds and

[5] See http://science.energy.gov/ber/research/cesd/terrestrial-ecosystem-science/.
[6] See http://science.energy.gov/ber/research/cesd/subsurface-biogeochemical-research/.

aerosols. It provides the national and international research community unparalleled infrastructure for obtaining precise observations of key atmospheric phenomena needed to advance the understanding of understanding atmospheric process and improve climate models. The facilities and capabilities of EMSL are available to the general scientific and engineering communities to conduct research in the environmental molecular sciences and related areas.

Within DOE, the ARM's major clients are the ASR, RGCM, and ESM programs of CESD (described above). The primary ARM objective is improved scientific understanding of the fundamental physics related to interactions between clouds, aerosols, and radiative feedback processes in the atmosphere. In addition, the ARM has enormous potential to advance scientific knowledge in a wide range of interdisciplinary Earth sciences. The ARM was the first climate change field research facility to operate cutting-edge instrumentation on a long-term continuous basis and at both fixed and varying locations around the globe. The ARM field research sites are designed to study the effects of aerosols, precipitation, surface flux, and clouds on global climate change. The fixed sites are located in three diverse climate regimes representing mid-latitude, polar, and tropical environs (i.e., the Southern Great Plains and the North Slope of Alaska in the United States and the Tropical Western Pacific). With its aerial measurement capability and mobile ground facilities, ARM provides the world's most comprehensive continuous observational capabilities for obtaining atmospheric data specifically for addressing the major scientific uncertainties in climate change.

Each ARM site uses a leading-edge array of cloud-, aerosol-, and precipitation-observing instruments to record long-term continuous measurements of atmospheric and surface properties. ARM also provides shorter term (months rather than years) measurements with its two mobile ground facilities and aerial measurement capability. The combination of high temporal resolution at discrete locations makes ARM observations uniquely suited for studying local cloud processes, many aspects of which remain poorly represented in climate models. The resultant data are available through the ARM's data archive. These data are used as a resource for over 100 journal articles per year, which represent tangible evidence of the ARM's contribution to advances in most areas of atmospheric radiation and cloud research. Additional programmatic information is available via the ARM homepage on the Internet.

Radar Wind Profiler and radio acoustic sounding system (RASS), ARM site at Barrow, Alaska.

EMSL offers users access to more than 60 major systems, including many one-of-a-kind analytical instruments for studying atomic to molecular to larger-scale processes, a supercomputing platform and associated computational chemistry software, and the in-house scientific expertise to help obtain high quality results in a timely fashion. By co-locating multiple types of capabilities and scientific expertise, EMSL serves as an ideal place for research teams

interested in integrating theory with experiment, as well as a place to conduct a wide range of single-investigator studies.

Detailed scientific knowledge of the physical, chemical, and biological processes occurring at the most fundamental levels is necessary to discover and fully utilize breakthroughs in areas such as hydrogen as a new energy source, improved catalysts and materials for industrial applications, insights into the factors influencing climate change and carbon sequestration processes, new approaches to managing legacy wastes such as radionuclide and heavy metal contamination, and making bioenergy sources a reality. The complex nature of DOE's energy, science, and environmental missions demands a wide range of leading-edge experimental and computational capabilities to enable scientists to conduct fundamental and multidisciplinary research using multiple experiment and computational approaches that will lead to scientific advances to help address the DOE missions. EMSL provides these leading-edge experimental and computational capabilities to the scientific community.

DOE's Next-Generation Ecosystem Experiments Project

The Arctic is undergoing a system-wide reorganization in response to an altered climate. The mechanisms responsible for this change have been unpredictable and difficult to isolate due to a large number of interactions among individual components of the system. The Next-Generation Ecosystem Experiments (NGEE) project will quantify the complex physical, chemical, and biological behavior of terrestrial ecosystems in Alaska. The project will focus on interactions that drive ecosystem-climate feedbacks through greenhouse-gas fluxes and changes in surface energy balance associated with thawing permafrost and threshold-dominated permafrost degradation and thermokarst formation. Research sites will be located along a bioclimate gradient that spans tundra and shrub-tundra transition zones on the North Slope and Seward Peninsula.

The new scanning precipitation radar at the Barrow, Alaska, ARM site.

The vision for the NGEE project is to deliver a high-resolution terrestrial system model for coupled thermal, hydrological, geomorphic, biogeochemical, and vegetation processes as needed to predict the evolution of a warming Arctic landscape and its feedback to the global climate system. This vision includes field observations, laboratory experiments, and modeling of critical and interrelated water, nitrogen, carbon, and energy dynamics and the important interactions, from the molecular scale to the landscape scale, that drive feedbacks to the climate system.

National Science Foundation (NSF)

The National Science Foundation funds basic climate research, modeling, and process studies. This research portfolio includes support to individual investigators and to groups such as the Center for Ocean-Land-Atmosphere Studies (COLA), the Center for Multiscale Modeling of Atmospheric Processes, and NCAR. With DOE as a partner, NSF funds NCAR to develop, maintain, and support the Community Earth System Model (CESM), a fully-coupled global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states. While basic climate research support has generally been directed through long-standing programs within the Directorate for Geosciences, a recent major new cross-directorate investment, Science, Engineering and Education for Sustainability (SEES), was introduced in FY 2010 and includes climate research topics such as decadal and regional prediction using DOE/CESD Earth System Models. SEES will continue over the next several years and will be at the nexus of NSF's effort to address challenges in climate and energy research and education.

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 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 meteorological agencies to ensure that appropriate risk information for hazards, vulnerabilities, and consequences is used to execute this mission.

FEMA's Planning Division administers the National Hurricane Program, which conducts hurricane evacuation studies, provides evacuation decision-making training, and provides a range of hurricane evacuation decision support tools to State and local government emergency management officials to develop their hurricane evacuation plans. Under an Interagency Agreement with the National Weather Service's National Hurricane Center (NWS/NHC), the NHC builds and utilizes its SLOSH (Sea, Lake and Overland Surges from Hurricanes) storm surge model as the hazard analysis basis for Hurricane Program studies, training, and decision support to State and local governments. .

FEMA's interagency collaboration and support is key to disaster impact assessments and 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 con–

sequences 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. 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 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 and 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, and other FEMA risk analysis activities, such as the Multi-Hazard Loss Estimation Methodology (HAZUS). The National Hurricane Program is the principal FEMA contact point for most meteorological matters, while the FEMA Risk Analysis Division is the primary contact for NFIP flood risk analysis.

Interagency Modeling and Atmospheric Assessment Center (IMAAC)

Under the National Response Framework, the mission of the 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 communicating with nontechnical decision makers. IMAAC plots and consequence reports show hazard areas, affected populations, potential casualties and/or fatalities, and damage estimates, including health effects, public protective actions, and worker protection levels based on Federal guidelines. The NWS is the primary source of meteorological observations and designated preferred model forecasts. The IMAAC also uses additional meteorological data from other

sources and/or higher-resolution in-house model forecasts if determined to be more 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). The NWS has the operational responsibility for the NTHMP, the goal of which is to ensure adequate advanced 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 (December 2004), 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.

FEMA Integrated Public Alert and Warning System (IPAWS) and PLAN/CMAS. The NWS will begin pushing watches, warnings, advisories, and special statements in Common Alerting Protocol (CAP) format to the FEMA IPAWS Alert Aggregator by December 2011.Warnings that pose an "imminent threat" to the general public will be broadcast to cell phones in the threat area compatible with the Personal Localized Alert Network (PLAN) or Commercial Mobile Alert System (CMAS). Each PLAN/CMAS message will have a maximum length of 90 characters. The message notifies the recipient of the alert type, expiration time, a one word description of the action to be taken, and name of the alert originator (i.e., NWS). All major wireless carriers have opted-in to provide the PLAN/CMAS service. Rollout of PLAN/CMAS is scheduled to begin in December 2011 in New York City and Washington, DC. Rollout for the remainder of the Unites States is scheduled for April 2012.

Other alerting systems, including the Emergency Alert System (EAS), may access NWS CAP messages in the Alert Aggregator for repackaging and/or redistribution.

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 or other environmental events. The NWS has a meteorologist permanently deployed at FEMA's National Response Coordination Center (NRCC) as a liaison to provide real-time information to national decision makers. Similarly, NOAA has a liaison deployed to the DHS National Operations Center.

NWS meteorologists provide forecasts in response to Incidents of National Significance such as the space shuttle Columbia recovery effort, Hurricane Katrina, volcanic eruptions in Iceland, and after major tornado events such as those in Tuscaloosa, Alabama and Joplin, Missouri during the spring of 2011. In addition, 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 for 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 CO-OPS observing systems, data, and products for ecosystem restoration and management. COASTAL also provides decision-support tools to aid managers and restoration practitioners to plan 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 product in particular incorporates water level and meteorological information measured at National Water Level Observation Network (NWLON) and Physical Oceanographic Real-Time System (PORTS®) stations. Storm QuickLook bulletins are posted for tropical cyclones that affect the United States coastline, but have also been created for the Deepwater Horizon oil spill and, in FY 2011, for elevated water levels in the Mississippi River. These bulletins provide near real-time, continuously updating oceanographic and meteorological data measured at affected water level stations and are displayed on the CO-OPS website and on the NOAAWatch (the NOAA All-Hazard Monitor) page. FY 2012 goals for this product are to enhance displays and make the product more dynamic. Also, 6-minute interval GOES transmission capability supports the NWS storm surge warning program when expected water level elevations are predicted or observed during coastal storms and hurricanes. COASTAL also provides aid to Tsunami Warning Centers, by supplying one-minute water level observations at coastal NWLON stations, as well as 15-second data as requested after a tsunami event. These data are used to assess the impact and damage of a tsunami. In FY 2012, NOS will be ingesting and displaying NWS-operated tsunami station data on the CO-OPS web page with NOS one-minute data for NWS Tsunami Warning Centers to access together with the web page tools.

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 damage assessment flights following natural disasters. They provide high-resolution photographs 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.

United States Air Force

Air Force Weather (AFW) enables Joint Warfighters to anticipate and exploit the weather for air, ground, space, cyberspace, and intelligence operations. As this applies to the 'Emergency Response and Homeland Security Services' category, AFW provides meteorological environmental information, products, and services required to support Air Force, Army, and other military operations in order to support the Nation's emergency response and homeland

security efforts. Different organizations within AFW support various aspects of the Nation's homeland security efforts:

- The Air Force Weather Agency's (AFWA) 1st Weather Group produces environmental products used to support both the daily and emergency response and homeland security operations of the U.S. Northern Command (USNORTHCOM) and the North American Aerospace Defense Command (NORAD). AFWA produces fine-resolution model and forecast products for use by the Defense Threat Reduction Agency (DTRA) in its hazard dispersion modeling and related emergency planning and response efforts.
- AFWA produces both CONUS and worldwide geospatial representations of current and forecast weather used to support the National Geospatial-Intelligence Agency (NGA) in its homeland security mission.
- AFWA provides backup to several NOAA operational centers, maintaining capabilities (for example) in severe weather, aviation, volcanic ash dispersion, and space weather, available if and when needed to support emergency response and homeland security.
- The Air Force's overseas Operational Weather Squadrons (the 17th OWS in Hawaii and the 21th OWS in Germany) may support emergency planning and response operations in their respective areas of responsibility. The Joint Typhoon Warning Center (JTWC), operated jointly with the Navy in Hawaii, routinely works with its sister US hurricane forecast centers to issue forecasts and warnings to protect US assets and interests across the Pacific and Indian Ocean basins.

U.S. Marine Corps Chemical Biological Incident Response Force

The Marine Corps' Chemical Biological Incident Response Force was established in 1996 in response to Presidential Decision Directive 39 to manage the consequences of nuclear, biological, and chemical (NBC) materials or weapons used by terrorists. This national-level asset is part of the reactivated 4th Marine Expeditionary Brigade–Anti-Terrorism, located at Indian Head, Maryland. It comprises specially trained and equipped Navy, Marine, and civilian personnel who can rapidly be forward deployed or otherwise respond to a credible threat of a chemical, biological, radiological, nuclear, or explosive (CBRNE) incident in order to assist local, State, or Federal agencies and designated unified incident commanders in the conduct of consequence management operations. Within the S-2 (Security Section), permanently assigned METOC forecasters provide specialized NBC dispersion forecast products and services that aid this organization in accomplishing a mission.

Department of Energy

Operational Meteorological Services at DOE Facilities

Site-specific meteorological services at DOE facilities date back to 1944 when the development, fabrication, and testing of atomic weapons and their accompanying national security and nuclear safety issues was in its infancy. Since that time, DOE has established, operated, and maintained operational meteorology programs and has also undertaken various atmospheric research projects at its field sites and offices. Early operational meteorology program requirements were augmented by the passage of the Clean Air Act and other Federal laws associated with

environmental protection. These requirements have been more recently reinforced through various DOE Orders, Standards, and Handbooks, as well as national voluntary consensus standards that specify requirements for a variety of meteorological services. Consequently, a meteorological monitoring program, of varying complexity, has become an essential component at each DOE site. The collection of quality-assured meteorological data, provision of weather forecasting services, and development of site-specific climatology from these meteorological measurements are important elements of a DOE Integrated Safety Management System (ISMS).

Successful implementation of a comprehensive DOE mission requires characterization of atmospheric processes. Meteorological data collection programs, diagnostic analytical assessments requiring meteorological information, and prognostic weather forecasting are integral to meeting DOE mission objectives. An understanding of the nature of the atmospheric domain, with its various dynamic and chemical aspects of energy-related phenomena, is vital to the successful implementation of DOE programs that address national energy security, scientific discovery and innovation, and environmental stewardship. As an example, a release of radioactive or chemically- or biologically-toxic material into the atmosphere may result in serious acute and chronic health effects on the workers and the public, as well as long-term environmental consequences. Various atmospheric processes play a role in determining the fate of hazardous materials released into the atmosphere which need to be accurately characterized. Consequently, a central theme of meteorology programs has been to protect worker and public health and safety, and the environment, on and around DOE facilities by accurately measuring and characterizing the relevant local atmospheric processes necessary to establish real-time and forecasted atmospheric transport and diffusion conditions.

DOE administers its operational meteorology programs through its various offices—including the Office of Health Safety and Security, the National Nuclear Security Administration, and the Office of Environmental Management—that have missions, requiring knowledge of the atmospheric sciences. Activities at DOE sites include support to daily operations (e.g., work-force safety under hazardous weather and emergency conditions) and national defense programs that require fundamentally sound and well-managed meteorological monitoring programs.

Nuclear Regulatory Commission (NRC)

The NRC Office of Nuclear Security and Incident Response coordinates NRC responses to nuclear facility emergencies through the activation of the NRC Operations Center. The Protective Measures Team dose analysts in the NRC Operations Center rely on the Radiological Assessment System for Consequence Analysis (RASCAL) model to assess offsite consequences in the event of a radiological accident at a NRC-licensed facility.

The NRC also maintains an interest in the transport and dispersion of airborne hazardous and nonradioactive materials on the safe operation of nuclear facilities and uses SAFER Real-Time to assess protective action levels for making recommendations in the event of a non-radiological accident at an NRC licensee.

U.S. Geological Survey (USGS) 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 Space 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 the 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 contracts, as provided by law and regulation.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NOAA Office of Oceanic and Atmospheric Research (OAR), 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 methyl mercury, 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. The FRD has also continuously observed and recorded meteorological conditions at the DOE Idaho National Laboratory (INL) and its environs since 1948. The 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 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), which is a nested network with sites of varying complexity that address 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.

DOE Meteorological Coordinating Council (DMCC)

The 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 NOAA and to 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 the following programs:

- Department of Commerce (DOC/NOAA) under an interagency agreement
- Management and 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 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 self-assessments of their individual meteorological monitoring programs 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 Office of Nuclear Security and Incident Response (NSIR) 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. NSIR is also planning to update its RASCAL dose assessment model to access NWS data via the internet.

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 of hydrologic conditions via flood warnings and river forecasts in the United States. The 122 Weather Forecast Offices (WFO), 13 River Forecast Centers (RFC), 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 resources 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. The RFCs are responsible for calibrating and operating complex hydrologic models based on rainfall, soil characteristics, precipitation forecasts, reservoir regulations, and several other variables in order to provide objective simulations of future river flows. Some RFCs, especially those in mountainous regions, also provide water-supply volume and peak-flow forecasts based on snow pack in high elevations. These forecasts are used by a wide range of decision makers, including those in agriculture, hydroelectric dam operation and electricity generation, and water resources management. Information from the RFCs is also the basis for local flood and flash flood warnings, watches, and advisories issued by the WFOs. These products emphasize flooding impacts from meteorological events based on geographic area, land use, time of the year, and other changing factors.

The HPC, located in Camp Springs, Maryland, is responsible for preparing quantitative precipitation forecasts (QPF), which are used by the 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.

The capabilities of NWS Hydrologic Services will be expanded by the Community Hydrologic Prediction System (CHPS)—a new operational framework, allowing for broad systems interoperability to include new water resources-related forecasts. CHPS will be fully implemented by January 2012. It will serve as the backbone for the National Oceanic and Atmospheric Administration's (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 streamflow, soil moisture, soil temperature, and many other variables directly related to watershed conditions via collaboration and sharing of data and algorithms with other Federal, university, and private-sector experts. 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 detection. 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 warnings, 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, like the National Ocean Service (NOS) and the Office of Oceanic and Atmospheric Research (OAR).

Integrated Water Resources Science and Services (IWRSS). A collaborative initiative between NOAA, the U.S. Army Corps of Engineers (USACE) and the U.S. Geologic Survey (USGS), IWRSS builds on progress made under AHPS and other NOAA water forecasting services. IWRSS will deliver new water resource information from the summit to the sea at higher spatial and temporal resolutions. This new information will include: 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 USGS, the Bureau of Reclamation, and the Bureau of Land Management in the Department of the Interior; with the 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, 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.

NOAA Office of Marine and Aviation Operations (OMAO)

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

U.S. Department of Agriculture

NRCS Hydrometeorological Observations

Since snowmelt provides 50-80 percent 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 more than 900 active manual snow courses and more than 800 automated Snowpack Telemetry (SNOTEL) monitoring stations. The 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 data from stream gages, major reservoirs, and 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 at the farm level to manage irrigation, the municipal level to plan anticipated water supply, and at the international level as the basis for water management decisions under treaties with Canada and Mexico.

The automated SNOTEL network mainly utilizes Meteor Burst technologies for transmitting data. This 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 more than 700 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 wildfire potential.

Water supply forecasts are produced bi-monthly 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 typically develops more than 10,000 seasonal water supply forecasts for 705 stream flow forecast locations in 12 western states. In addition, the program provides daily water supply guidance forecasts for 138 western basins. These products provide 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 are valuable to climate change researchers and in developing reliable projections of climate change. It has been projected that changes to the hydrologic cycle in the western states, resulting from changes in snow pack, will increase the water supply challenges the states face. Monitoring data provides assistance to water managers at all levels to adapt to climate change impacts.

The SSWSF Program provides a variety of climate and water supply products that are used to assess drought in the West. 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 180 Soil Climate Analysis Network (SCAN) sites in 40 states and U.S. territories. These SCAN sites monitor soil temperature and soil moisture, which support national drought monitoring, production agriculture, and climate change research.

U.S Army Corps of Engineers

In its civil operational activities, the USACE uses a network of about 10,850 land-based gages. About 55 percent of these sites collect meteorological data, 35 percent collect a combination of hydrologic and meteorological data, and 10 percent collect hydrologic or water quality data. The meteorological gages commonly measure precipitation and temperature. All data are used in the regulation of USACE dams and other water projects, for flood control, navigation, hydroelectric

power, irrigation, water supply, water quality, and recreation. The USACE funds or partially funds nearly half of all the gages it uses.

meteorological sites. The USACE also funds the NWS for hydrometeorological studies and funds the USGS for maintaining hydrometeorological data collection services for 2479 sites. The rest of the sites are maintained by the USACE. Services performed by USGS vary by site and by year, and can include site visits, maintenance of equipment, replacement of damaged equipment, field measurements for verification of data, and continuous monitoring of data results. About 90 percent of all USACE sites provide real-time data via satellite, microwaves, meter bursts, landlines, or radio. Data from USACE gage sites are available to the NWS, and to other Federal, state, and local agencies.

U.S. Geological Survey

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).

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.

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 site (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. During Hurricane Irene, the USGS deployed 260 temporary, mobile streamgages (storm-tide sensors) to observe water levels, resulting from storm-tide in coastal waters along the Atlantic Coast from South Carolina to Maine. The data are available at http://107.20.206.65/Irene2011/IreneMapper.html#.

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.

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, the 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 the 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 estimations (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 2012, if there is sufficient funding within NOAA to support it, the HMT will spin up a second regional implementation in the southeastern United States.

Storm-scale Hydrometeorology Research. The Coastal-Inland Flood Observation and Warning (CI-FLOW) project uses the National Severe Storm Laboratory's (NSSL) multi-sensor rainfall estimates to drive an NWS-distributed hydrologic model that predicts streamflow to help the NWS improve flash flood warnings. CI-FLOW is a major component of NOAA's Integrated Water Forecasting program called the Coastal, Estuary Resource Information System (CERIS). In addition to 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.

Nuclear Regulatory Commission (NRC)

The NRC conducts meteorological research to support licensing activities. Current research activities include quantifying the storm surge from severe weather events, updating the baseline data used in hydrometeorological reports (HMR), and updating the methods used to estimate the effects of extreme precipitation events. The HMR work will be extended in FY 2012 to consider the influence of orographic features. In addition, new work will be initiated to start looking at flooding from a probabilistic perspective. 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 Department of the Interior's Bureau of Reclamation.

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, Marine Corps, and Coast Guard), the discussion below first describes that service's operational organizations, followed by a description of the principal meteorological products and services provided by these organizations.

U.S. Air Force (USAF)

Operational Organizations

Air Force Weather (AFW). AFW enables Joint Warfighters to anticipate and exploit the weather...for air, ground, space, cyberspace, and intelligence operations. 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 is functionally organized under the Director of Weather (AF/A3O-W), Directorate of Operations (AF/A3O), Deputy Chief of Staff, Operations, Plans, and Requirements (AF/A3/A5), Headquarters Air Force. The Director of Weather oversees Air Force-wide training, organizing, and equipping of AFW organizations, to include the following functions:

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

- Advocating and fielding standardized weather equipment to support worldwide training and combat operations

Air Force Weather mission statement

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

Air Force personnel in the weather 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 personnel must understand warfighter tactics, techniques, and procedures, and help decision makers mitigate weather impacts and take advantage of weather conditions. AFW personnel support Air Force, Army, Joint, and DOD conventional and special operations at various garrison and deployed locations worldwide.

AFW personnel aligned with Army units directly support the G-2 intelligence centers and Amy Fire Support operations. Weather is a vital part of the intelligence estimate and is an essential element that supports the military rapid-response planning process. Weather 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 effectively evaluate, integrate, and synchronize weather effects for both enemy and friendly courses of action.

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.

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 (OWS) 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. Per AFW's 3-tier structure to support forward operations via reachback technology, AFWA's 2nd Weather Squadron (2 WS) at Offutt AFB provides global coverage of forecaster-in-the-loop products to exploit environmental information necessary to effectively plan and conduct military operations at all levels of war, including providing dedicated support to the intelligence community, as well as backup for two national weather centers.

- The 1st Weather Group aligns stateside weather operations with the USAF warfighting initiative overseeing the OWSs. The 1 WXG has three subordinate OWSs whose areas of responsibility are within the continental United States: the 15th, 25th, and 26th OWSs. 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) decision makers, 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, the 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 mission-execution weather analyses, forecasts, and briefings for Air Force, Army, National Guard, and Reserve forces operating anywhere around the world.

- The 15th OWS's area of responsibility includes 120 installations/sites in a 22-state region of the northeastern United States.
- The 17th OWS's area of responsibility covers over 95-million square miles of the Pacific region including Australia, Korea and Japan.
- The 21st OWS's area of responsibility includes Europe, Greenland, and most of Africa.
- The 25th OWS's area of responsibility includes 68 installations/sites in an 11-state region of the western United States.
- The 26th OWS's area of responsibility includes 70 installations/sites in a seven-state region of the south central United States.
- The 28th OWS's area of responsibility includes sites throughout the U. S. Central Command, including southwest Asia and the Horn of Africa.

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 responsible OWS.

Special Operations Weather. USAF special operations units provide limited forward weather observations in denied areas and transmit them 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 The National Oceanic and Atmospheric Adminstration's (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 organizations 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

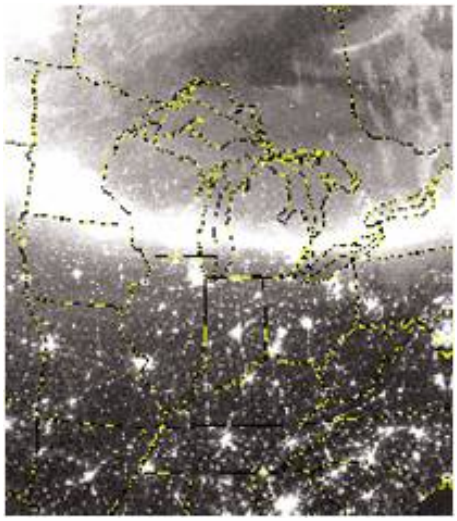
weather personnel augment the active duty force at all three tiers. In some cases, the AFRC provides very unique weather-related services not duplicated in the active duty force, such as AFRC's 53rd Weather Reconnaissance Squadron (53 WRS) (see "AFRC Hurricane Hunters," below) and the ANG's Weather Readiness Training Center.

To augment AD OWS operations, AFRC organized two operational weather flights, each staffed by AFRC weather personnel, capable of augmenting an OWS either in the CONUS or overseas. Additional AFR weather personnel serve as individual mobilization augmentees assigned to various active AF weather organizations at all echelons, typically in staff, forecasting, or scientific roles. There are weather traditional reservists working with an AFRC Remotely Piloted Aircraft (RPA) unit. There are also AFR weather personnel in Air Reserve Technician positions, i.e., combined full-time Civil Service/AFR military positions, employed by HQ AFRC as a staff weather officer and by the 53rd WRS as aerial reconnaissance weather officers. Lastly, AFRC civil service and contract weather personnel provide weather services at AFRC-operated bases in the CONUS.

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

USAF Products and Services

Satellite Services. AFW operates a satellite data processing center, ingesting and storing worldwide meteorological satellite (METSAT) data. The Defense Meteorological Satellite Program (DMSP), which provides cloud, upper air, and space environmental data, is a vital source of global weather data used to support combat operations and has been collecting weather data for U.S. military operations for more than five decades. Onboard sensors provide AFW and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery, plus temperature and moisture sounding data. The DMSP also supplies direct, real-time readouts of regional imagery and mission-sensor data to DOD land-based and shipboard terminals located worldwide.



DMSP captures aurora borealis, over the Midwest. The aurora was pushed toward the equator by a November 4, 2003 geomagnetic storm. Source: AFWA Website.

There are two primary operational DMSP satellites in polar orbit at about 450 nautical miles (nominal) at all times. The primary weather sensor on DMSP is the Operational Linescan System, which provides

continuous visual and infrared imagery of cloud cover over an area 1,600 nautical miles wide. Worldwide coverage of weather features is accomplished every 12 hours providing essential data over data-sparse or data-denied areas. Additional satellite sensors measure atmospheric vertical profiles of moisture and temperature. Military weather forecasters can detect developing patterns of weather and track existing weather systems over remote areas, including the presence of severe thunderstorms, hurricanes, and typhoons.

In addition to DMSP polar-orbiting data, AFW receives stored data from NOAA's Polar-orbiting Operational Environmental Satellite (POES) constellation and real-time high-resolution data from NOAA's Geostationary Operational Environmental Satellite (GOES) East and West; European METSAT (EUMETSAT) -7, -8, and -9 geostationary satellites, and Meteorological Operational Polar (METOP) orbiters; as well as the Japanese Multifunctional Transport Satellite (MTSAT). (AFWA currently receives data from the National Aeronautics and Space Administration's (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS), Tropical Rainfall Measuring Mission (TRMM), and Aqua Advanced Microwave Scanning Radiometer-E (AMSR-E); NOAA's Washington Volcanic Ash Advisory Center (VAAC); and NOAA's Space Weather Prediction Center (SWPC).

Space Launch Support. USAF meteorological support for space launches is discussed in the Other Specialized Services section.

Air and Space Natural Environment Modeling and Simulation. The Air Force Director of Weather carries out the DOD Air and Space Natural Environment Modeling and Simulation Executive Agent (ASNE MSEA) responsibilities of managing, coordinating, and implementing all aspects of modeling and simulation, relating to the Air and Space Natural Environment domain to include, but not limited to, planning, programming, monitoring, and reporting across all DOD components in accordance with the Under Secretary of Defense for Acquisition, Technology, and Logistics Memorandum to the Secretary of the Air Force, designating the Department of the Air Force as the MSEA for air and space natural environment representations. The DOD ASNE MSEA ensures DOD communities who use simulations for their training, acquisition, testing, planning, experimentation, and analysis have the right tools, infrastructure, and databases necessary to represent the air and space natural environment and its effects.

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

The radar display on board a WC-130J aircraft used by the 53 WRS Hurricane Hunters. Source: 53 WRS website.

Air Force Aviation Weather Support. AFWA's 1st Weather Group (1 WXG) has three subordinate CONUS OWSs which form the backbone of CONUS regionally focused, "reachback" weather operations, providing a variety of weather forecast products and support to units assigned to and/or deployed into their respective Areas of Responsibility (AORs). These three OWSs along with the USAFE and PACAF OWSs, the 21th OWS and the 17th OWS respectively, provide operational weather support and resource protection for personnel and military installations in their respective AORs. The 28th OWS provides focused "reachback" weather operations in support of Air Force Central Command (AFCENT) operations in Southwest Asia. Operational support to the USAF, Army, Navy, Marine, Guard, Reserve and regional Combatant Commanders includes graphical analyses, aviation terminal aerodrome forecasts, severe weather watches/warnings and advisories, and mission execution forecasts, such as aviation hazards and enroute and target forecasts. Additionally, the OWSs provide flight weather briefings to aircrews, operating within their AOR without home station support or as requested by base or post-level weather forces. The 15th OWS, located at Scott AFB, IL, provides short-term backup services for the National Weather Services' Storm Prediction Center (SPC) and Aviation Weather Center (AWC). In the event of an extended or catastrophic outage at either SPC or AWC, essential staff would relocate to the

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

AFWA facility at Offutt AFB, NE, where system and communications infrastructure exists to support relocation backup of these critical national missions.

At AF bases and Army 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 AF operations, these weather professionals are normally assigned to a flight under an operations support squadron of an AF flying wing; however, individuals from the weather flight are integrated into flying squadron mission planning and execution processes. For Army operations, the Battlefield Weather Airmen professionals are normally assigned to combat weather teams at all levels of Army support. The weather airmen are integrated into all aspects of Army operations. In this capacity, weather forces supporting AF and Army 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.

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 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.

Air Force Aviation Weather Products and Services

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 Air Force's primary automated mission planning systems are providing valuable lessons learned for NextGen's development. AFW's AFWA Ensemble Prediction System is also providing valuable path-finding insight into the utility and delivery of probabilistic aviation impacts that is a requirement of NextGen's 4-D data cube.

Weather System Upgrades. In FY 2012, 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.

U.S. Army

USA Weather Support Structure

Weather support within the Army is a mix of Army and Air Force 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 U.S. Army, 6 January 2010). This interservice regulation describes the responsibilities of USAF support components and of the Army Commands and Army Service Component Commands (ASCC) for providing weather support. Under this agreement, 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. The USAF assigns AFW personnel to provide direct and indirect weather support to the Army Commands, ASCCs, and installations. The Army provides assigned Air Force personnel the equipment necessary to perform their Army support mission in the tactical environment. The Army also provides facilities and host services to Air Force personnel assigned to Army installations.

The U.S. Army Forces Command, U.S. Army Europe, U.S. Army Pacific, U.S. Army Special Operations Command, Eighth U.S. Army, and the U.S. Army Training and Doctrine Command (TRADOC) have Air Force weather personnel, providing daily installation and tactical weather support. The Army provides operational weather 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 the Army Test and Evaluation Command. SMDC provides weather support to the Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll through a Meteorological Environmental Test Support contractor.

Headquarters, Department of the Army (HQDA.) The Office of the Deputy Chief of Staff (ODCS), G-2, establishes weather policy within the Army, coordinates on AF weather policy issues with the Air Force Director of Weather (HQ USAF/A3/5), submits validated Army weather requirements and priorities to the HQ USAF/A3/5, coordinates with the AF on Army-AF and Joint Service weather operational concepts and doctrine, serves as the Army staff proponent for meteorological satellite capabilities and issues, and reviews and coordinates Army-related support issues with the Office of the Secretary of Defense, the Joint Staff, the Department of the AF, other Services, HQDA staffs, ACOMs, DRUs, ASCCs and other Federal agencies. HQDA, ODCS, G-2, employs two civilian meteorologists to formulate weather policy and work meteorological issues for the Army Staff.

The Office of the Deputy Chief of Staff, G-3, validates and prioritizes weather support requirements and programs to meet Army requirements, sets priorities for weather support for Army training and contingencies, coordinates with the HQ USAF/A3/5 on Army weather program and resource issues, Army Guard and Reserve weather issues, and Army installation weather support requirements.

U. S. Army North (USARNORTH). USARNORTH employs one civilian meteorologist as an advisor to the Commander, USARNORTH on all issues involving meteorology, oceanography,

and space weather. This individual applies meteorological and oceanographic policies and objectives to cover all USARNORTH mission requirements, and coordinates on USARNORTH exercise and contingency plans.

Training and Doctrine Command. 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 Table of Organization and Equipment (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 HQDA 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. The USAICoE employs one Department of the Army Civilian (DAC) to head the Weather Proponent Office. This DAC leads USAICoE weather proponent efforts in the JCIDS process, and in doctrine, organization, training, materiel, leadership, 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. 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.

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 anTOEs (MTOE) for AFW teams, supporting USA operations. The TOEs and MTOEs direct the

type and amount of tactical equipment required by a weather team, indicating also the level of support needed for this weather team to accompany its host Army organization. The CAC SWO is the USAF's weather point of contact for implementing MTOE structure changes for support to Army modular forces. The CAC SWO also arranges for or provides environmental data, concepts of operation, and weather subject- matter expertise for programs, projects, documents, and studies. 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 provide 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 at Fort Rucker, Alabama.

USA Products and Services

U.S. Army Artillery. The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the legacy MMS, AN/TMQ-41. The MMS-P design supports the new generation of indirect fire artillery weapons. The system is housed in a Standard Integrated Command Post Shelter (SICPS)/Command Post Platform (CPP), transported on a High Mobility Multipurpose Wheeled Vehicle, and operated by a crew of two soldiers. The MMS-P provides highly accurate meteorological (MET) data to adjust artillery fire and achieve first round hits and fires for effect. The MMS-P uses the MM5 Mesoscale Meteorological Model to assimilate data from a variety of sources to provide the best meteorological messages to the user in a timely fashion. An operator interface, in conjunction with the message generation and formatting software, facilitates communication between the MMS-P and all other systems that require interoperability with the MMS-P. Existing systems are scheduled to be replaced by the next generation of Profiler (Computer Meteorological Data-Profiler [CMD-P]) beginning in FY 2013. The CMD-P is designed to reduce the logistics footprint to a laptop configuration that is located in the Tactical Operations Center (TOC), thus eliminating the SICPS/CPP, support vehicle, and crew. Additionally, the local ground sensor will be removed to further reduce the logistical footprint, and the system interface with the Advanced Field Artillery Tactical Data System will be a local area network (LAN) connection in the TOC. The system will no longer require the Global Broadcast Service (GBS) receiver suite as part of the profiler system but will rely on the GBS connection from the TOC LAN. The system software will be capable of providing Field Artillery Computer MET and Gridded MET messages on demand with or without an operator in-the-loop. The CMD-P will undergo development testing in FY 2011 and operational testing in FY 2012. Fielding is planned to begin in FY 2013.

Distributed Common Ground System–Army Weather Services. The Distributed Common Ground System–Army (DCGS-A) is the Army's premier intelligence, surveillance, and reconnaissance (ISR) enterprise for the analysis and processing, exploitation, and dissemination of information and intelligence data across all echelons. It is the Army component of the DOD Distributed Common Ground/Surface System and interoperable with Army, Joint, and Coalition battle command systems. The program of record Integrated Meteorological System (IMETS) is the Army's current meteorological decision-aid support system. A key component of IMETS, the Integrated Weather Decision Aid (IWEDA) application, allows warfighters to display the effects of weather phenomena on weapon systems, personnel, and operations for mission planning. The Army, through the Program Manager DCGS-A, is integrating the AF Joint Environmental

Toolkit into DCGS-A weather services and providing web-centric weather support for DCGS-A and Mission Control intelligence and command/control users. The DCGS-A will host weather capabilities, including JET, on common Army hardware systems and utilize the latest Ozone/Widget and DCGS-A Application framework dissemination technology. Initial fielding of DCGS-A weather services occurred as part of the ISR Surge software builds for DCGS-A V3.1 in FY 2011. By the end of FY 2012, the remaining IMETS systems will be displaced with the fielding of weather services on DCGS-A V3.1 and the follow-on DCGS-A Software Baselines.

U.S. Army Test and Evaluation Command (ATEC). The Developmental Test Command (DTC), a subordinate command of ATEC, is responsible for providing operational meteorological support to USA RDT&E. Under responsibilities established in AR 115-10/ 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 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.

Artillery Meteorological Education and Training. The U.S. Army Field Artillery School, Fort Sill, Oklahoma, is the proponent for upper air meteorological support to the Army and home of the Field Artillery Meteorology Course. The AN/TMQ-52A/B MMS-P is utilized to conduct surface and upper air observations. The MMS-P is a suite of meteorological sensors and associated software/models which will provide the field artillery with current and/or expected weather conditions at a point where the weapon munitions is expected to engage a target (Target Area Met).

U.S. Navy

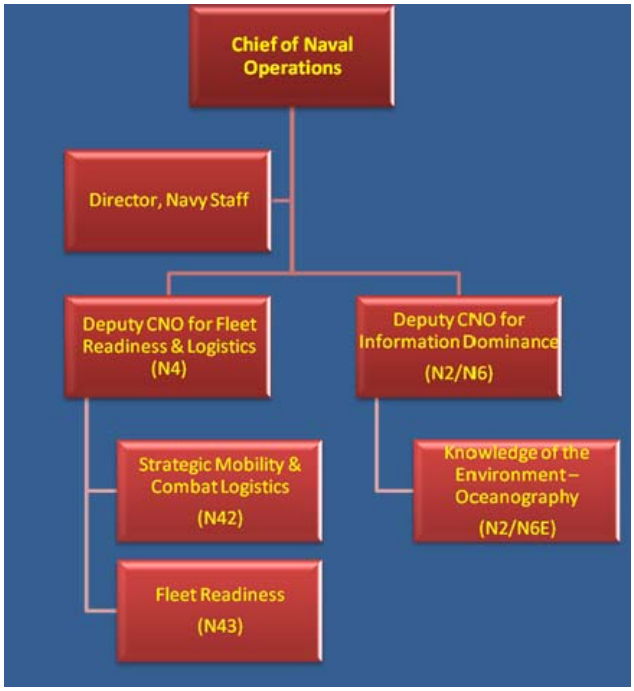
Operational Organizations

Oceanographer of the Navy. The Oceanographer of the Navy (OPNAV N2/N6E) is the Chief of Naval Operations’ (CNO) principal advisor on plans, requirements, resources, programs, and

policies for Meteorology and Oceanography (METOC), Maritime Domain Awareness, and Navy Space (including Positioning, Navigation, and Timing). As the Oceanographer and Navigator of the Navy, he serves as the focal point for matters related to the Naval Oceanography Program (NOP) and related marine science fields. The expanded responsibilities enable the Oceanographer to directly integrate METOC knowledge into other Naval mission areas and major programs. He represents the research and development (R&D) requirements of Commander, Naval Meteorology and Oceanography Command (CNMOC); his staff works closely with U.S. Fleet Forces Command (USFF), CNMOC's Immediate Superior in Command, and the Office of Naval Research (ONR) to ensure the proper resources are available to advance mission requirements. As the functional manager for Geospatial Information and Services, he works within the National System for Geospatial-Intelligence and liaises with the National Geospatial-Intelligence Agency. He acts as Naval Deputy to the NOAA Administrator and represents theNOP in interagency and international forums. He ensures Navy and Marine Corps equities, regarding remote sensing from space and through all manned and unmanned vehicle capabilities, effectively meet warfighter needs for maintaining Battlespace Awareness and Knowledge Superiority.

The Oceanographer provides for the standardization of METOC, maritime geospatial information, astrometric and precise-time models, databases, and environmental predictive techniques. He coordinates NOP, Navigation Policy, and architectures with Navy and DOD science and technology and RDT&E, along with related efforts in civilian agencies and develops means for transition from research to operational applications.

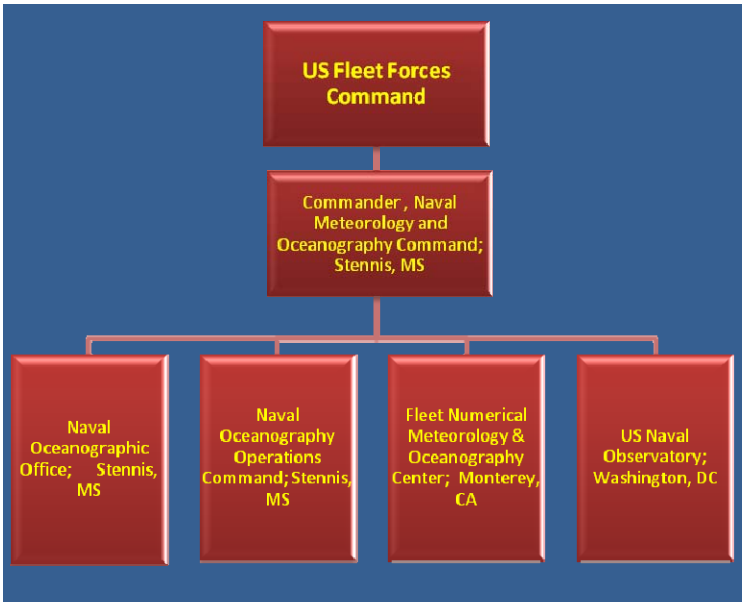
Task Force Climate Change. In May 2009, the Chief of Naval Operations appointed the Oceanographer of the Navy to head the Task Force Climate Change (TFCC). The TFCC addresses emerging Navy needs and develops comprehensive approaches, regarding Arctic and global climate change to guide future Navy public, policy, and strategy discussions. Further, the 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



Location of the Oceanographer of the Navy (OPNAV N2/N6E) in the staff supporting the Chief of Naval Operations.

Roadmaps provide holistic, chronological, science-based guidance for future Navy action from now through 2040.

Naval Meteorology and Oceanography Command. The Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) conducts METOC operations through the Naval Oceanography Operations Command (NAVOCEANOPSCOM) located on the Stennis Space Center (SSC) complex in Hancock County, Mississippi. NAVOCEANOPSCOM consists of several geographically dispersed unit-level commands that provide small, agile forward-deployed teams and reach-back services from their centers of excellence for Antisubmarine and Mine Warfare, Expeditionary Warfare, Weather Services, and Navigation. Precise Time and Astrometry services are provided from the U.S. Naval Observatory (USNO) in Washington, DC. 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 oceanographic phenomena on platforms, sensors, and weapon systems. Navy and Marine Corp METOC personnel provide for safety of flight and navigation in support of naval, joint, and combined forces operating on and in the world's oceans.



Organization for Operational Meteorology and Oceanography under CNMOC. Source: U.S. Navy.

COMNAVMETOCCOM serves as the operational arm of the NOP. COMNAVMETOCCOM is a third echelon command, reporting to USFF. COMNAVMETOCCOM's assets are globally distributed at shore facilities in fleet concentration areas and larger production centers in the U.S. COMNAVMETOCCOM forces also deploy as detachment teams to larger ships (aircraft carriers, amphibious ships, and command and control ships) as well as to forward operating areas as requested.

COMNAVMETOCCOM is focused on providing critical environmental knowledge to the war fighting disciplines of Anti-Submarine Warfare; Naval Special Warfare; Mine Warfare; Intelligence, Surveillance and Reconnaissance; and Fleet Operations (Strike and Expeditionary), as well as to the support areas of Maritime Operations, Aviation Operations, Navigation, Precise Time, and Astrometry.

Major activities and additional subordinates within the command currently include:

- NAVOCEANOPSCOM, Stennis Space Center, MS
- Fleet Weather Center Norfolk and Fleet Weather Center San Diego with subordinate units and detachments

- Naval Special Warfare Oceanography Center in San Diego, CA, (with components and detachments in Stuttgart, Germany, Norfolk, and Pearl Harbor)
- Naval Oceanography Anti-Submarine Warfare Centers in Yokosuka, Japan, and Stennis Space Center, MS (with subordinate detachments)
- Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, MS
- Fleet Survey Team, Stennis Space Center, MS
- Naval Ice Center, Suitland, MD
- Fleet Numerical Meteorology and Oceanography Center (FNMOC), Monterey, CA
- USNO, Washington, DC
- Naval Meteorology and Oceanography Professional Development Center, Gulfport, MS, with detachments in Norfolk, VA; San Diego, CA; Pearl Harbor, HI; and Yokosuka, Japan

Naval Oceanography Operations Command. NAVOCEANOPSCOM, headed by the Commander, Naval Oceanographic Operations Command, is an echelon four command that serves as the principal operational organization, reporting to CNMOC and coordinates and manages efforts among field activities under the Operational Oceanography Program to optimize warfighting resources, support safe operations, and enhance decision superiority within the battlespace through superior understanding and exploitation of the environment. The Command encompasses the nine warfighting and enabling directorates: Aviation Operations, Maritime Operations, Fleet Operations, Precise Time and Astronomy, Navigation, ISR (Intelligence, Surveillance, and Reconnaissance), Mine Warfare, Naval Special Warfare, and Anti-Submarine Warfare. Each directorate determines how that directorate's services are delivered globally. Each directorate reports to a single Navy Captain who functions as Naval Oceanography's Chief Operating Officer.

The Commander, NAVOCEANOPSCOM supports the combatant commanders and national missions, U.S. interagency and international partners. The major NAVMETOCCOM production centers (NAVOCEANO, FNMOC, and USNO) support the Commander, NAVOCEANOPSCOM with enabling capability.

The command's operational model is knowledge-centric, based on deploying small and agile specialized teams forward with 24/7 reach back to major production centers for data and expertise and to operational mission-specific centers of excellence. Emphasis is placed on standardizing service delivery models for each directorate, value added automation, and enabling decision superiority (i.e. turning forecasts into decisions). The operations support portion of USN/USMC FY 2012 budget funds the day-to-day environmental support to the DOD, the Active and Reserve Components of the Navy and Marine Corps, ten unified commands, and other agencies as directed by the Chief of Naval Operations. Over 1,228 military and civilian personnel conduct these activities at more than 22 locations worldwide.

Fleet Numerical Meteorology and Oceanography Center. FNMOC, which is a 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, Stennis Space Center, Mississippi. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO is responsible for the administration of a fleet of seven ocean-class hydrographic survey vessels.

United States Naval Observatory. USNO 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, USNO 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. USNO 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. USNO 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. USNO 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 the DOD. They are also used extensively by other government agencies and the public at large.

Navy Products and Services

Surface Transportation Operations. Dangerous weather and safe navigation are the top two Fleet concerns. The Naval Meteorology and Oceanography Command is actively engaged with Fleet forces to provide valuable physical environmental knowledge to aid warfighting decision making. Personnel are integrated with the Fleet, where they provide in situ observations, run tactical decision aids, and interpret environmental data to provide decision support to Fleet commanders.

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

Highly trained meteorology and oceanography specialists are deployed to support planning and operations. Reach-back teams work with onboard personnel to refine data, develop models, conduct forecast analyses, and deliver high-quality information to Fleet commands.

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

Aerographer's Mate 3rd Class Heath Collins uses a dew point calculator in the Meteorology and Oceanic Center aboard the Nimitz-class aircraft carrier *USS Ronald Reagan* (CVN 76) Source: http://www.navy.mil/view_galleries.asp.

Maritime Weather Operations. Navy meteorologists and forecasters are assigned to Maritime Forecasting Centers in Hawaii and Virginia. Core maritime weather services include Optimum Track Ship Routing (OTSR) and weather forecasting services to support transoceanic voyages and coastal operations. OTSR services:

- Provide hazardous ocean and weather advisories and divert recommendations to ship Commanding Officers and Masters at sea
- Include sortie recommendations for potentially damaging weather conditions in port
- Provide preliminary climatologic outlooks for transit and mission planning
- Routine ship weather forecasts and aviation weather forecasts for ship-based helicopters, to include high wind and seas warnings and local area warnings for Fleet Concentration Areas

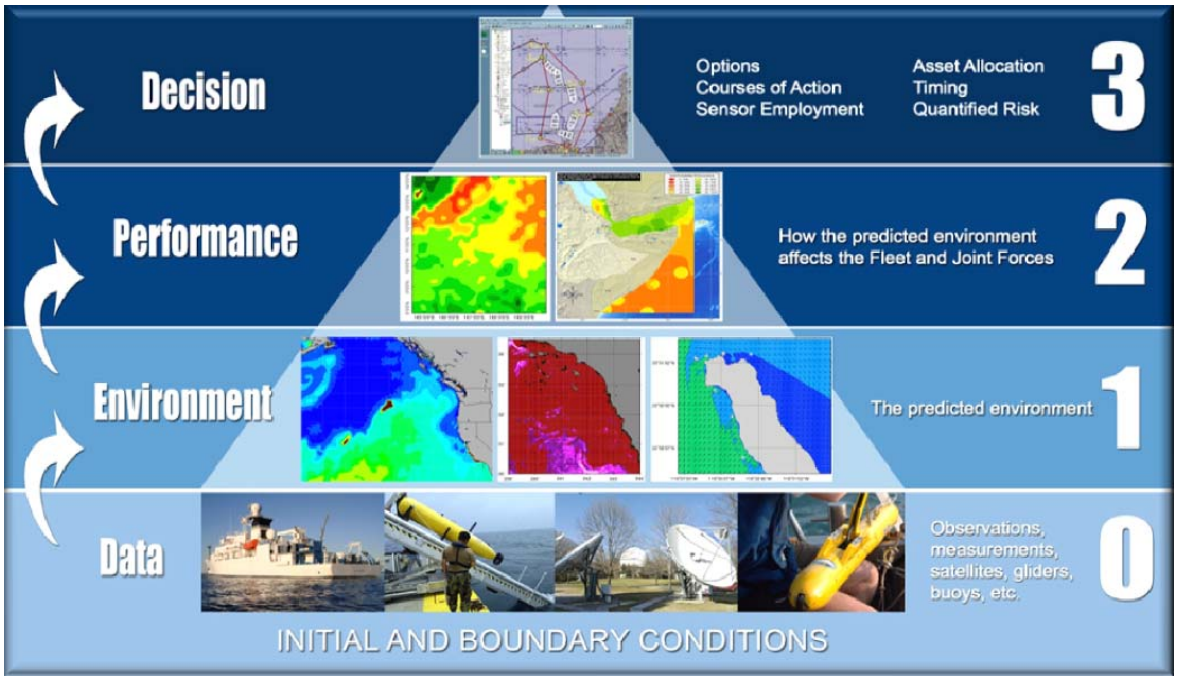
Joint Typhoon Warning Center (JTWC). The JTWC, established by the U.S. Pacific Command, is jointly manned with U.S. Air Force personnel. JTWC services include tropical cyclone forecasts, warnings, and other products for DOD warfighters, operating in the Pacific and Indian Oceans. JTWC, located in Pearl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

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

Naval METOC underpins every aspect of naval operations and warfare. It provides an affordable and sustainable competitive advantage to the Nation and protects the substantial National investment in both afloat and ashore force structure. The NOP, which is supported by ocean engineering, operational supercomputing, and operations research, in recent years reinvented itself to meet the warfighting needs of the operators and the fiscal needs of today's Navy. Increasingly, costs are leveraged in the Joint, interagency, and international arenas to deliver capabilities at a shared cost. The NOP 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.

Battlespace On Demand (BonD). Naval oceanography is about generating competitive advantage across the warfighting and shaping spectrum by turning the physical environment into superior information that provides decision superiority to forces in the field. The Navy strategy to achieve this, Battlespace on Demand, consists of overlapping tiers (see figure) 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



The Battlespace on Demand operational concept.

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, 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 influence sensors, weapons, platforms, and people, providing opportunities and restrictions for successful operations and warfighting. BonD defines 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. BonD provide actionable recommendations on force allocation and employment that directly enhance safety and warfighting effectiveness.

Littoral Battlespace Sensing (LBS). LBS is the Department of the Navy's IPE approach for atmospheric and oceanographic data collection, data processing, and data/product dissemination to users. LBS facilitates better tactical decision making by enabling a system of networked sensors to share information through interoperability with Naval and joint networks and information systems. It addresses gaps with respect to environmental data fidelity (in time and space) that have been shown to play a critical role in force disposition and force posture in current and future naval missions. LBS is a critical persistent IPE technology, a key component of the BonDd framework, supporting Battlespace Awareness Joint Capability Area through 2025 and beyond.

FNMOC Numerical Weather Prediction 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 decision makers 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.
- 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, 7x24x365 support 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 that provide ocean thermal structure and currents in support of anti-submarine and mine warfare operations, or near-shore wind, sea, and surf forecasts that directly support Fleet Operations through ship-to-objective maneuver. In many cases, the outputs of the 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 Special Operations Forces, 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 meteorological and oceanographic observations and satellite imagery to complement its models and applications products. These include on-demand extracts from its global observational database, a full range of DMSP Special Sensor Microwave/Imager products, ERS and QuikScat scatterometer wind products, a comprehensive

view of tropical cyclones via the FNMOC TC Web Page, and various experimental satellite products fielded for evaluation in conjunction with the Naval Research Lab (e.g., satellite imagery that enhances the visualization of airborne sand and dust). FNMOC also hosts the USGODAE Monterey Data Server in support of the Global Ocean Data Assimilation Experiment (GODAE). 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 ARGOS Global Data Assembly Centers, hosting the complete collection of quality-controlled ARGOS temperature/salinity profiling float data.

Many of FNMOC's products are distributed to users over the Web via the PC-based METCAST system, and subsequently displayed and manipulated on the user's PC with the Joint METOC Viewer (JMV) software. This includes all standard METOC fields, synoptic observations, and satellite imagery. For those who require only graphical display of model-predicted meteorological or oceanographic fields, FNMOC provides a Web-based capability called WxMap (i.e., "Weather Map"). WxMap, requiring only a Web browser for access, allows the user to select and quickly display predicted 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. Note that FNMOC also hosts a DOD High Performance Computing Modernization Program (HPCMP) Distributed Center, which is integrated closely with POPS.

In addition to its primary role of focused support to the warfighter, FNMOC also 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 National Hurricane Center (NHC) relying on them heavily.

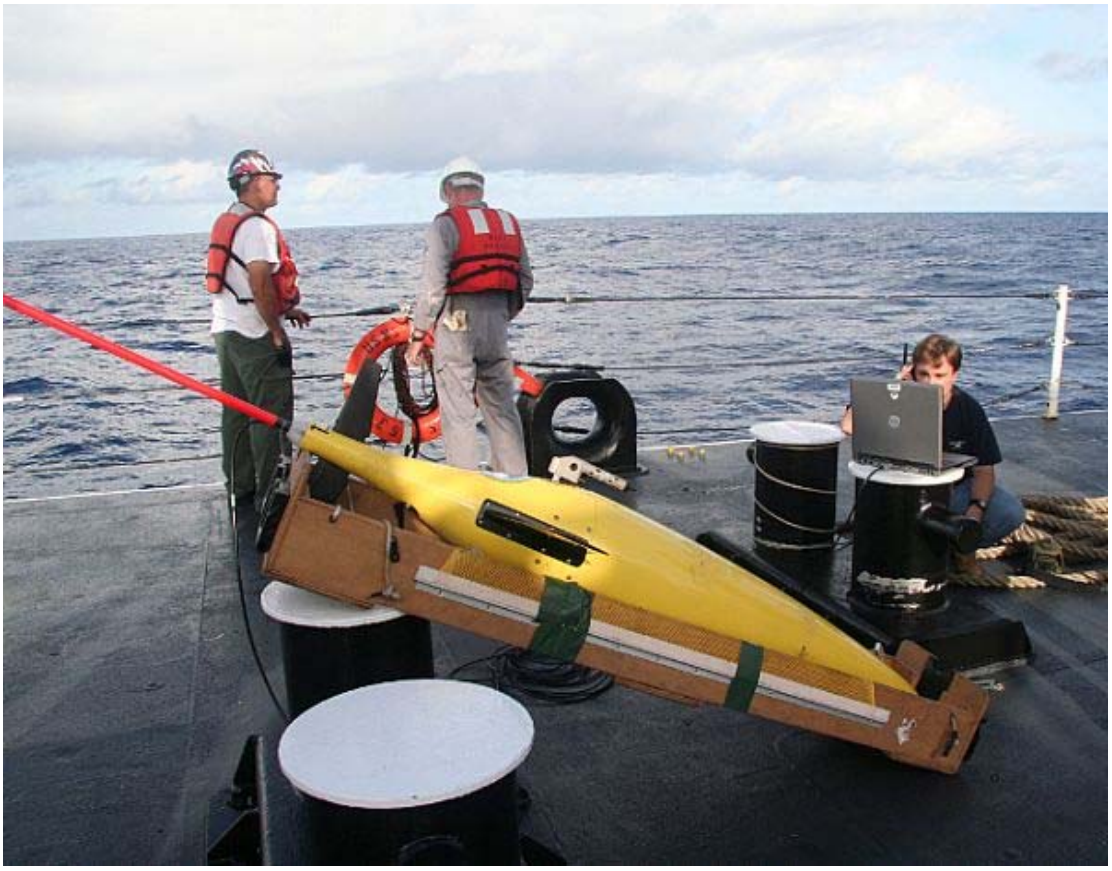
FNMOC benefits greatly from collocation with its supporting R&D activity, the Marine Meteorology Division of the Naval Research Laboratory (NRL/MRY). NRL/MRY is a world-class research organization, with focus on weather-related support to warfighting. FNMOC and NRL/MRY share space, data, software and computer systems, and together with the nearby Naval Postgraduate School represent one of the largest concentrations of weather-related intellectual capital in the Nation. Collocation and close cooperation between research and operations, such as exists between NRL/MRY and 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 to 96 hours. The 1/8 degree (14km/7.5nm) 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 (3km/1.7nm) regional NCOM domains of order 20 by 20 degree sizes provide high-resolution ocean forecasts in areas of Navy and national interest. Twelve regional NCOMs are on line with 24 planned by 2014. Global and regional NCOM products and data fields are shared with our 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



An oceanographer from NAVOCEANO establishes a satellite connection to the Glider Operations Center at NAVOCEANO before launching the seaglider unmanned underwater vessel from the Military Sealift Command oceanographic survey ship *USNS Henson* (T-AGS 63). At the time, the *Henson*, which is designed to collect physical oceanography data in deep water, was conducting survey demonstrations with the Brazilian Directorate of Hydrograph and Navigation as part of Oceanographic-Southern Partnership Station 2010, an oceanographic surveying and information exchange program between subject matter experts from partner nations. Source: http://www.navy.mil/view_galleries.asp.

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's National Centers for Environmental Prediction (NCEP).

NAVOCEANO is the Navy's primary processing facility for a number of polar-orbiting and geostationary satellite collection systems from NOAA, the 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 impact flight operations and mission accomplishment. These include: wind speed and direction, cloud ceiling, precipitation, turbulence, visibility, icing, and severe weather such as thunderstorms. An accurate forecast is often the deciding factor in mission success and for the safety of the pilot and their aircraft. Navy weather observers and meteorologists analyze current physical environmental conditions and forecast atmospheric and oceanographic phenomena, impacting naval flight operations, by leveraging state-of-the-art computer models.

The Navy's Hazardous Weather Display & Detection Capability adds low-cost Doppler weather sensing and warning capability to CVN, LHA, and LHD Class ships through AN/SPS-48E and G radar systems. It provides critical organic safety of flight and maritime sensing to afloat platforms.

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.

Precise Time and Astronomy. This program provides astronomical and timing data for all DOD navigation and positioning activities as well as command, control, and communications architectures. This program funds upgrades and life-cycle replacements to the Master Clock at

the USNO for Global Positioning System (GPS III) and maintenance of star catalogs and celestial reference frames for strategic systems.

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. Each Regional METOC Center began using WSI weather date services for aviation support in the fall of 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 (MEF) headquarters, intelligence battalions, Marine Wing Support Groups (MWSG), and Marine Wing Support Squadrons (MWSS). There are three MEFs strategically positioned for global response. The I MEF, which is based in southern California, and the III MEF, which is forward based in Okinawa, Mainland Japan, and Hawaii, report to the Commander, Marine Forces Pacific. The 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 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 task-equipped to provide a limited level of METOC support to combat elements other than an ACE (e.g., a Command Element, 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 Joint METOC Coordination Center 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 processing equipment. During operations, team members organically collect METOC products, data, and information from the nearest deployed Meteorological Mobile Facility-Replacement [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. The highest level of METOC support to the MAGTF and ACE-specific operations is the deployment of the MetMF(R). The MetMF(R) provides a METOC support capability similar to that found in garrison METOC facilities. The MetMF(R) is normally employed as part of MWSS to a forward operating base and is the only realistic option for large-scale MAGTF operations. Once established ashore, the MWSS may detach small METOC support teams with portable ancillary equipment to a forward base in support of ACE units that are separated from the main airbase. This redeployment also provides the MetMF(R) with a forward data collection capability that significantly enhances METOC situational awareness and overall support efforts to the entire MAGTF. With appropriate Service personnel augmentation, the MetMF(R) is also capable of serving as host for an in-theater Joint METOC Coordination Center, during joint operations and exercises.

The MetMF(R) NEXGEN is a mobile system that provides tactical meteorological support to the Marine Air Ground Task Force. This system will replace the legacy MetMF(R) with current and emerging state-of-the-art technologies, offering a smaller overall size and increased mobility. These advancements will significantly enhance the meteorological capabilities of the Marine Corps Expeditionary Forces.

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

Naval Integrated Tactical Environmental System (NITES IV). Each MWSS and METOC MST is equipped with a NITES-IV suite to provide forward METOC support. The NITES IV is a modular system, used to provide limited METOC support in a stand-alone mode with increasing capabilities realized with the addition of 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.

Naval Integrated Tactical Environmental System (NITES-Next). NITES-Next will be the primary METOC processing, exploitation, and dissemination system, converting atmospheric and ocean weather information into warfighter impacts, closes capability gaps for safety and mission planning in degraded communication environments.

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.

U.S. Coast Guard

The U.S. Coast Guard (USCG) is a military, multi-mission maritime service and one of our Nation's five armed forces. The USCG protects the public, the environment, and the economic interests in the Nation's ports and waterways, along the coast, on international waters, and in other maritime regions, as required to support national security. The USCG has a long history of environmental observations and science support. Support for meteorological operations and supporting research is detailed in other sections of this plan.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

National Unified Operational Prediction Capability (NUOPC) Research Partnering Initiative

The Navy, AFW, and NOAA/NWS partner in this tri-agency management organization. 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. NUOPC focuses on the next-generation systems for global NWP with full implementation by 2020, allowing for possible future expansion into other areas of numerical prediction. NUOPC established its Initial Operational Capability in January 2011, which provides a National multi-model global ensemble exchanged between NOAA, the Navy and the Air Force on a one degree grid for 72 variables out to 16 days. Upgrades to ensemble systems will continue and the resolution of the exchanged ensemble members will be doubled in 2012 to one half degree, and doubled again to one quarter degree by 2015.

The NUOPC multi-model global ensemble forecast system has the potential to establish the United States as the premier computer-modeling group in the world. Improvements in predictive capability will 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. Finally, NUOPC efforts are laying the ground work for the next generation environmental prediction system.

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 the 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.

The Air Force Weather Web Services (AFW-WEBS) is a centralized web service capability, providing access to environmental information appropriate to all levels of operation and command. The program is designed to leverage net-centric capabilities and geospatial display services via AFW-WEBS to provide the operational warfighting community a single point of access to the total AF authoritative environmental content from sources across the AFW enterprise. By 2015, AFW-WEBS will have evolved into the single web site optimized for accessing authoritative AF meteorological information and services. All appropriate meteorological information will be serviced in geospatially enabled formats for direct integration into warfighter systems and decision cycles. Consistent environmental characterizations of key mission-impacting weather parameters improved by the FITL process will be used as a common source for both visualized web content and for direct M2M services accessed by warfighter systems. AFW forces will employ AFW-WEBS capabilities to improve the quality, accuracy, and effectiveness of all weather support processes. Finally, C2, ISR, and MP systems will employ AFW-WEBS products and services to help more decision makers maintain better BA and use the knowledge gained from this process to plan and execute more effective missions.

Cloud Forecasting. In applied meteorological R&D, the AF is improving cloud forecasting techniques by increasing the resolution, using a new cloud interpretation/typing scheme, integrating available satellite (to include non-traditional METSAT) into the cloud analysis, incorporating cloud optical properties, and blending numerical weather prediction with forecast cloud advection techniques. The AF has transitioned key advances in tactical decision aids into operations, permitting improved forecasting of electro-optical system performance and generation of cloud and target scene visualizations for training, system development, and mission rehearsal.

Weather Forecast Modeling for Air Force and Army Operations. The Weather Research and Forecasting (WRF) model is the next generation community model and is another area of AFWA participation in research and development in collaboration with NCAR, NOAA's NCEP, NOAA's Earth Systems Research Laboratory (ESRL), the University of Oklahoma's Center for the Analysis and Prediction of Storms, and others. AFWA initially implemented WRF operationally in 2006 and will continue with sponsorship and funding of development at NCAR and ESRL, along with test and evaluation of real-time runs of the WRF model runs as well as the WRF-Chem (which takes into account chemical and aerosol constituents). 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 near the surface and in the low levels of the atmosphere. This enables AFW forces to provide better battlespace characterization for missions such as (but not limited to) low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also allows for assessment of trafficability for ground forces.

AFWA is in the process of developing a capability called the Air Force Weather Ensemble Prediction Suite (AFWEPS). AFWEPS output, at both the mesoscale and global scale, will provide better meteorological intelligence for the warfighter by objectively quantifying the forecast certainty of mission-impacting meteorological parameters to optimize operational risk management for all echelons of decision making. It will provide probabilistic algorithms for high-impact variables and quantify biases, allowing concise, focused products. The successful proof-of-concept Joint Ensemble Forecast System prototype laid the groundwork to construct an operational ensemble prediction capability and the prototype products are being produced and evaluated daily at AFWA as part of pre-operational RDT&E, and in parallel operations in the US Pacific Command and US Central Command AORs.

Research Partnering Initiatives. AFW is partnering with the NWS and the Navy in the NUOPC project. This partnership exists to enable a tri-agency joint global atmospheric ensemble forecast system. NUOPC is an integration of ongoing efforts coordinated by a tri-agency management organization. The NUOPC vision is a National NWP system with interoperable components built on common standards and framework (Earth System Modeling Framework) with managed operational ensemble diversity and a national global NWP research agenda to accelerate science and technology infusion.

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 RDT&E 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, which has responsibility for the USA's Research Development and Engineering Centers and ARL.

Battlefield Environment Division, ARL Computational and Information Sciences Directorate. The Battlefield Environment 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 the development of remote sensing capabilities to gather critical data. Numerical modeling R&D includes the 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 Battlefield Environment 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 Joint Polar Satellite System (JPSS) program office located at the NASA Goddard Space Flight Center to coordinate on Army satellite data, information requirements, and applications development. The division works closely with the AFWA to provide new DOD-relevant weather products for evaluation and operational hosting on AFWA's web page and web-enabled technologies, delivering meteorological products and databases to the warfighter. Furthermore, the division supports the field artillery community in the area of meteorological accuracy of artillery systems and related issues.

Battlefield Environment Division, Atmospheric Modeling Applications Branch. The Atmospheric Modeling Applications Branch addresses the development of the next-generation mission execution forecast model (very short term forecasts) and web-enabled weather decision support tools.

Meteorological forecast model applications are focused on Nowcast modeling and meso/micro-scale NWP development, improvements, and evaluation. The Nowcast modeling system will produce locally updated high-resolution meteorological data in 3-6 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 Air Force and joint DOD weather centers, and insure effective assimilation and fusion of local battlefield weather observations into each Nowcast modeling cycle.

Warfighter Decision Aids developed in the branch utilize meteorological model gridded output at all scales to provide the commander a tactical advantage with validated and verified, web-enabled decision support tools 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. Such decision tools play an important role in the mission planning and execution processes associated with both man-in-the-loop and autonomous command and control systems, presenting operators with simple color-coded weather impacts products, contributing to overall tactics and route-planning decisions at all echelons of the battlefield.

Battlefield Environment Division, Atmospheric Dynamics Branch. The 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 the soldier and systems. Projects and capabilities in the branch include follow on research to the successful diagnostic 3D Wind Field (3DWF) model to produce an Atmospheric Boundary Layer Environment prognostic model for meteorology in urban and complex domains that addresses temperature, aerosol, and moisture dynamics as well as winds. The 3DWF model is applied as the core capability in the 24/7 detailed wind field and airborne hazard monitoring capability to support garrison emergency operations called the Local-Rapid Evaluation of Atmospheric Conditions system.

Basic research in the Atmospheric Dynamics Branch also includes improved theoretical models for propagation through optical turbulence and fundamental characterization of mechanical

turbulence for modeling wind gusts and its effects in urban domains. These models support research on biomimetic and biologically inspired methods for autonomous systems to sense and react to the local environment. Atmospheric effects are measured and modeled for emerging technologies in terahertz-band sensing and imaging, wide-band acoustics applications, and atmospheric propagation for emerging ground-based, solid-state, high-energy laser systems.

Battlefield Environment Division, Atmospheric Sensing Branch The Atmospheric Sensing Branch develops technologies for scientific and operational sensing of the state of the atmosphere, electro-optical and acoustic propagation, and aerosols. Recent work has focused on exploiting ultra-compact Doppler LIDAR systems; experimental and theoretical developments to better understand electro-optical and acoustic propagation in urban environments; and aerosol characterization research.

Models and codes under development will provide valuable tools for the investigation of environmental effects on acoustic sensor performance. The decision aid models created from 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 (laser radar), passive infrared imaging, or passive spectral radiometric systems have significant importance for ISR operations.

Aerosol research focuses on the ubiquitous, but relatively unknown, fraction of organic carbon aerosols and natural biological aerosols in the atmospheric boundary layer. Research to further develop and employ ultraviolet-laser induced fluorescence and two-dimensional angular optical scattering techniques will improve the understanding of both kinds of aerosols in natural atmospheric aerosols.

ARL Army Research Office. The Army Research Office, Research Triangle Park, North

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

Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamical and physical processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10s of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investigator program and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer over land, where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding, modeling, and quantifying of atmospheric effects on soldiers, materials, and weapon systems. The research examines quantification, classification, and dispersion of battlefield materials; the effects of heterogeneous terrain features on airflow; and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Other areas of research focus on acoustic and electromagnetic energy propagation and detection/imaging techniques. Special funding areas are also managed. The Defense University Research and Instrumentation Program provides funds for instrumentation needed to support ongoing research activities. Also basic research under the Small Business Innovative Research Program is managed for selected topics.

U.S. Army Corps of Engineers R&D

The USACE is responsible for reviewing emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The USACE Engineer Research and Development Center (ERDC) develops tactical decision aids (TDA) and geospatial analysis tools to interpret and help the warfighter to understand the impact of weather on terrain and provide actionable information of terrain, atmospheric, and weather effects on units, systems, platforms and soldiers in support of Mission Command and Intelligence, Surveillance and Reconnaissance planning. TDAs are transitioned to the Digital Topographic Support System (DTSS) and the Commercial Joint Mapping Tool Kit (CJMTK).

ERDC supports Army weapon systems RDT&E with all-season solutions for mitigating adverse environmental effects on Army operations. Basic and applied research is conducted on energy and mass transfer processes at and near the terrain surface. ERDC develops databases and models for predicting the state of the terrain, including surface temperature, soil moisture, TDAs, and geospatial tools, supporting mobility analysis and sensor performance. These products transition to research and engineering programs, including advanced technology demonstrations and specific programs of record such as DTSS and CJMTK.

Army Test and Evaluation Command

ATEC is responsible for providing operational meteorological support to Army RDT&E. Under responsibilities established in AR 115-10/AFJI 15-157, ATEC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support Army and other DOD RDT&E activities at eight Army installations.

Enhancements to ATEC Four-Dimensional Weather System. The Army RDT&E Meteorology Program is continuing to collaborate with the National Center for Atmospheric Research (NCAR) on enhancements to the ATEC Four-Dimensional Weather (4DWX) System, which is the backbone of the meteorological support infrastructure at the Army test ranges. ATEC 4DWX modeling capabilities include WRF-based real-time four-dimensional data assimilation at seven Army test ranges, and Global Meteorology on Demand, a globally relocatable mesoscale modeling system to support Army RDT&E (including ATEC distributed and virtual testing) at locations other than the Army ranges. Output from the 4DWX mesoscale model forecasts and analyses is used as meteorological input to atmospheric dispersion, noise propagation, ballistic trajectory, and other range applications models to simulate many tests and their associated impacts. The 4DWX system contributes to improved test planning and conduct, selection of more representative locations for test sensors, inclusion of realistic atmospheric effects in virtual testing, and forensic analyses of meteorological effects on test results.

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 Dugway Proving Ground (DPG) test operations. The DPG ensemble system uses both the Mesoscale Model Version 5 (MM5) and the WRF model as members of the ensemble set, which typically uses 30 members with varying physics packages, boundary or initial conditions, and model type. During FY 2011, the computers installed at each test center to execute the 4DWX models were replaced with a consolidated system located at DPG, with a backup to be located at another test center. The consolidated system was much less expensive than purchase of separate computers, and will provide easier and more consistent security upgrades and maintenance.

System enhancements during FY 2011 included improvements to the WRF model's capability for deterministic numerical weather prediction specific to each test range, continued work on a hybrid data assimilation system to accept new types of data, and continued development of ensemble and probabilistic techniques. Installation of the AutoNowcaster thunderstorm prediction system at the Redstone Test Center (RTC) was completed. System enhancements during FY 2012 will include continued WRF and data assimilation development focused on forecasting improvements at each range, in addition to advances which apply generally to all WRF applications, including continued work on the hybrid data assimilation approach. In addition, we will continue enhancements to the AutoNowcaster implementations at RTC and at White Sands Missile Range, and will evaluate additional AutoNowcaster implementations at ranges where radar data necessary for AutoNowcaster operations are available.

Meteorology Division at DPG West Desert Test Center. The Chief of the Meteorology Division at DPG's West Desert Test Center serves as the ATEC Program Manager for Meteorological Support to Army RDT&E. Specialized services provided by the division include: (1) technical assistance to the ATEC operational meteorological teams/branches; (2) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; and (3) technical assistance to the DOD CB defense modeling community in the development of new CB hazard assessment models. Division employees also serve on various

national and international committees, addressing issues related to meteorological measurements, atmospheric dispersion modeling, CB hazard assessment, mountain meteorology, and air quality.

Atmospheric Sciences and Meteorological Support to the High Energy Laser Systems Test Facility (HELSTF). HELSTF, which is an ATEC 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, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HEL testing by providing measurements of atmospheric conditions that are extremely important to propagation of any HEL beam 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. Efforts for FY 2012 include work required to modernize the atmospheric measurements and data collection/analysis capabilities needed to support new laser testing facilities.

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 will influence 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.

Earth System Prediction Capabilities. The Navy is partnering with NOAA and other agencies on ESPC (Earth System Prediction Capabilities). The ESPC focus is on next-generation systems for Global Numerical Weather Prediction, allowing for possible later expansion into other areas of numerical prediction with full implementation by 2020. The primary deliverable of ESPC is a multi-model global ensemble forecast system, coupling the domains of land, sea, atmosphere, ice, and space 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, snow storms), better cost avoidance for weather sensitive industries (agriculture, transportation, utilities, defense), and better informed decision making for industry, defense, and the general public.

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

NOAA 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 operates the national civilian Space Weather Operations Center, coordinating with Air Force Weather (AFW) personnel at Offutt Air Force base in the production of joint products, ensuring a consistent message on the space weather forecast across both civilian and Department of Defense (DOD) customer bases. The SWPC provides forecasts, alerts, and warnings to customers on a 24 hour-per-day, seven day-per-week basis. SWPC products are synthesized from over 1,400 data streams to provide observations of the solar terrestrial environment which include x-ray flux, charged particles, and magnetic field changes on the Sun and the Earth, and in interplanetary space. The 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 operations, space exploration, radio navigation, high-altitude polar flights, high-frequency communications, remote intelligence gathering, long-line power and data transmissions, and geophysical exploration. The SWPC also 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.

United States Air Force

The mission of AFW is to enable joint warfighters to anticipate and exploit the weather...for air, ground, space, cyberspace, and intelligence operations. As this applies to the 'Space Weather Services' category, AFW provides space environmental information, products, and services required to support DOD operations as required, providing actionable environmental impacts information directly to decision makers.

AFWA's Space Weather Flight is the DOD's reachback 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 the 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.
- Impacts on electromagnetic signals, influencing High Frequency (HF) communication, Ultra High Frequency (UHF) communication, and Global Positioning System (GPS) satellite navigation signals.
- Increased drag on satellites in low-earth orbit.
- Increased interference or false returns to sunward or poleward looking radars.
- Potential health impact of radiation exposure to high-altitude aviators and those flying over polar regions.

The 2 WS also provides both immediate and extended backup support for the SWPC. The backup may include the use of on-site personnel or augmentation from SWPC depending on severity and expected duration.

The 2 WS space weather technicians located at Offutt Air Force Base (AFB), Nebraska, 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 and magnetosphere. 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, Massachusetts
- Detachment 4, Holloman AFB, New Mexico (relocating to Kirtland AFB, New Mexico)
- Detachment 5, Kaena Point, Hawaii
- San Vito, Italy (contract site)

Solar optical and radio telescopes at Learmonth, Australia. Source: U.S. Air Force.

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 (RIMS) and the Solar Radio Spectrograph (SRS) 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. The 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. The 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, mission execution, 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 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 (NGDC) in Boulder, Colorado. NASA's 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, Massachusetts, provides ionospheric scintillation data from a global network of 22 UHF and L-Band receivers, supporting AF command and control satellite systems and strategic long-range radar systems. Additional data are provided by the U.S. Geological Survey (USGS), which operates a network of ground-based magnetometers, primarily in the northern hemisphere, that provide AFWA with critical measurements of the Earth's geomagnetic field and its variances.

From space, the Defense Meteorological Satellite Program (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 top-side 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 GOES-14 satellite monitors solar X-ray emissions and provides near real-time display at AFWA and the SWPC in Boulder, Colorado. AFW also leverages space-based data from NASA and other agencies.

AFW will continue to lead the DOD in space weather operations in FY2012 and beyond. In FY 2012, AFW will maintain its aggressive posture to upgrade its solar equipment and processes, along with providing new or upgraded facilities for some solar locations.

U. S. Geological Survey

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 (http://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 (NSWP).

Federal Emergency Management Agency (FEMA)

FEMA has initiated an Interagency Planning effort to develop a Concept of Operations Plan (CONPLAN) that will identify roles and responsibilities of each agency during a Space Weather Event. FEMA is working with their interagency partners to define the scope of this CONPLAN and to create a workable scenario on which to base the plan. Currently, this effort is in its infancy stage and participants in this effort are still being identified.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NOAA Space Weather Prediction Center

The SWPC conducts applied research in solar-terrestrial physics and develops techniques for forecasting space weather storms. Research and development at SWPC emphasizes the utilization of fundamental research to improve operational space weather forecast capabilities. The activities are intended to foster and enable focused research in order to identify, investigate, and recommend new modeling capabilities, research results, and observational advances to improve SWPC forecasts, products, and services. Through these activities it achieves its principal objective of infusing the benefits of new research and technology developments into operational space weather products and services, in order to improve the utility and capabilities of the SWPC alerts, watches, warnings, and forecasts for its customers.

Activities include:

- Maintaining awareness of scientific advances and new techniques being developed to identify improved data-analysis techniques, forecast models, and observational systems that have potential for significantly improving the forecast guidance provided by space weather forecasters;
- Conducting, supporting, and managing focused research on data-analysis techniques/ algorithms, forecast models, and observational systems that have the potential to significantly improve the forecast guidance provided to space weather customers;
- Developing, testing, validating, and verifying promising numerical codes and forecast techniques, emerging from the research community to determine their potential benefits for possible use in operations;
- Communicating priorities and operating procedures to maintain fair and open interactions with all stakeholders (operational, research, academic, international, and commercial) and to stimulate improvements in space weather analysis and forecasting applications;

Current projects at SWPC include the following:

- Improvements to the definition and parameterization of coronal mass ejections (CME) for input into operational solar-heliospheric models that forecast the propagation of solar disturbances through interplanetary space from the Sun to the Earth.
- Testing of geospace/magnetosphere models with the goal of transitioning research models into operations so that SWPC can provide customers with regional forecasts and specifications of space weather impacts.
- Development of the Whole Atmosphere Model by extending the NCEP Global Forecast Systems weather model up to the near-space environment thereby providing specification and forecasts of the impacts of the lower atmosphere weather systems on space weather.

USGS

Research conducted within the USGS Geomagnetism Program targets space-weather applications that use ground-based magnetic-observatory data. Recent work has concentrated on the development of a real-time, storm-time disturbance index, Dst, which serves as a standard proxy measure of the magnetospheric equatorial ring-current intensity and is an important input to numerous operational physics-based models of the coupled magnetospheric-ionospheric system. Ongoing work is aimed at developing real-time, mid-latitude magnetic-disturbance indices needed for measuring localized magnetic disturbances across the contiguous United States; real-time, high-latitude auroral-zone indices needed for monitoring geomagnetic substorms; and real-time estimates of geomagnetically induced currents that represent a hazard for electric power grids. All of these projects are part of a larger project for developing time-dependent geomagnetic-disturbance hazard maps. Other current research projects are focused on analysis of individual historical magnetic storms, long-term changes in geomagnetic activity, and long-term changes in solar-terrestrial interaction, all of which are important for understanding the potential hazard posed by magnetic storms that will occur in the future. The research staff of the USGS Geomagnetism Program provides leadership and technical guidance to Intermagnet, an international consortium that is dedicated to promoting the global integration of magnetic-observatory operations. They also represent the USGS in numerous other national and international forums. The role of the USGS Geomagnetism Program within the larger NSWP was recently summarized in a feature article in the journal *Space Weather* which is published by the American Geophysical Union and is co-sponsored by the ISES.

National Aeronautics and Space Administration (NASA)

The Heliophysics Division of 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 configurations of interplanetary space. The three areas of concentration in the Heliophysics Division's research program are theory, data, and modeling. To support the data collection effort that characterizes the heliophysical environment, the division operates a fleet of 17 missions involving 26 spacecraft. The region of space characterized is huge, extending from the Sun itself to the outer edges of the solar system and the heliosphere. To extend the research effort, as part of the Living With a Star Program, NASA 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 the Internet. The Advance Composition Explorer (ACE) spacecraft, an Explorer program research activity in extended mission status, provides data on the condition of the solar wind upstream 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 Heliospheric 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. The Solar Dynamics Observatory (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 within the research and analysis program and the Targeted Research and Technology portion of the Living with a Star Program. The Supporting Research and Technology Program funds instrument development that improves observing capabilities towards better resilience against extreme space weather conditions, ultimately feeding models with the most reliable data. As a quality assurance activity to validate the national research community model development, the agency operates the Community Coordinated Modeling Center (CCMC), an interagency collaborative activity that includes NOAA, DOD, and the National Science Foundation (NSF). The CCMC 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 NSWP.

Department of Energy National Nuclear Security Administration

The U.S. Department of Energy National Nuclear Security Administration (DOE/NNSA) supports the NSWP through the collection and distribution of operational data, through participation in research missions with space weather applications, and through the development of space weather models such as DREAM and AE/AP-9. One of the most significant contributions is the collection and distribution of space weather data from DOE/NNSA instruments on U.S. government satellites in geosynchronous and GPS orbits. DOE/NNSA geosynchronous observations have been available continuously since 1979 and, since 1989, measurements span energies from a few electron volts (eV) to tens of MeV. Geosynchronous observations are also available in real time from multiple satellites which constitutes an important (but under-exploited) resource for driving real-time specification and forecast models. DOE/NNSA space weather resources on GPS satellites, include both particle measurements for the space radiation environment and impulsive RF measurements that provide important (but under-exploited) information on ionospheric structure and density with global

coverage (24 satellites). GPS observations cover the time period from 1983 to present so, as with other geosynchronous measurements, they provide an important resource for space weather climate models and for validation and testing of specification and forecast models.

DOE/NNSA, through the national laboratories, has also provided important space weather capabilities through the construction and operation of scientific instruments that also provide important space weather information. These include the plasma spectrometer on ACE (L1 solar wind), particle detectors on RBSP (ring current, radiation belts, solar particles), Forté (ionospheric structure and density), and others. DOE/NNSA has also supported the development of space weather models. These include the next-generation climatology model (AE/AP-9) for spacecraft design and the DREAM model which is a real-time assimilative model for the radiation belts. Both models rely heavily on geosynchronous and GPS observations. A third is RAM-SCB which is a model of the ring current. DOE/NNSA strives to partner with other entities with space weather interests and is exploring new ways in which its data, models, and space weather services can be more fully utilized to support the national space weather enterprise.

National Science Foundation

The 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 2011 was estimated at $14 million and is expected to be around the same level in FY 2012.

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 orbiting 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 Weather Forecast Offices (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 NOAA's

National Environmental Satellite, Data, and Information Service, 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. Largely through the Center for Operational Oceanographic Products and Services (CO-OPS) program line, NOS acquires water levels, currents, and other physical oceanographic and meteorological data and distributes these data and circulation predictions as elements of an integrated NOS program. This program 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 NOS Nautical Charting Program, NOS Shoreline Mapping Program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate Services Program. Approximately 182 of the 210 NWLON stations 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 150 stations are 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 AWIPS system. By FY12, two NWLON stations in Texas will be upgraded to Sentinels, which are specially-designed water level stations that are built to withstand a Category 4 hurricane, and these stations will include a full suite of meteorological sensors. The President's FY12 Budget Request proposed reduced funding for NWLON meteorological sensors; therefore, there will not be any further upgrades of NWLON stations to include meteorological sensors.

Physical Oceanographic Real-Time System (PORTS®). PORTS® is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource

management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS® measures and disseminates observations and predictions of water levels, currents, salinity, bridge air gap and many meteorological parameters, needed and requested by the mariner to navigate safely. There are 20 existing PORTS® systems that comprise a total of 84 PORTS® water level stations. Currently, 66 of these stations contain at least one meteorological sensor (anemometer, barometer, air temperature sensor or a visibility sensor).

The PORTS® systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. PORTS® is a partnership program in which local operating partners fund the installation and operation of the measurement systems. The largest of NOS' existing installations is composed of over 100 separate instruments. The smallest consists of a single water level gauge and associated oceanographic and meteorological instruments. Regardless of its size, each PORTS® installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting United States ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill 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 Automated Identification System, Electronic Chart Display Information Systems ECDIS, and Vessel Traffic Systems VTS. Visibility sensors are the most recent sensor type to be integrated into the PORTS® systems, and there are currently two visibility stations installed in Mobile Bay PORTS®. More visibility installations are planned for Narragansett Bay and Chesapeake Bay PORTS® in FY12.

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 and numerical circulation models allows nowcasts and predictions of up to five parameters (water level, current speed and direction, winds, water temperature and salinity) within the boundaries of the eleven models at locations where physical measurements are not available. In FY11, Chesapeake Bay Oceanographic Forecasting System was upgraded from a two-dimensional to a three-dimensional hydrodynamic model, and the Delaware Bay and Tampa Bay models became operational. Three new models planned for release in FY12 are the Northern Gulf of Mexico (including Galveston Bay and Mobile Bay), Columbia River and San Francisco Bay models. Ongoing developments will enable the operational forecast systems to incorporate ecological forecast models and integrate the output with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management and homeland security.

The NOS Continuous Real-Time Monitoring System (CORMS). CORMS was designed to operate on a 24 x 7 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, 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 fix the station remotely or initiate emergency maintenance, thereby decreasing downtime of a particular station or sensor. FY12 plans for CORMS 3 include additional enhancements to render internal reports on station statistics and tighter quality control threshold values used to flag questionable data.

United States Coast Guard

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 supporting 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 heavy lift 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 direct 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)

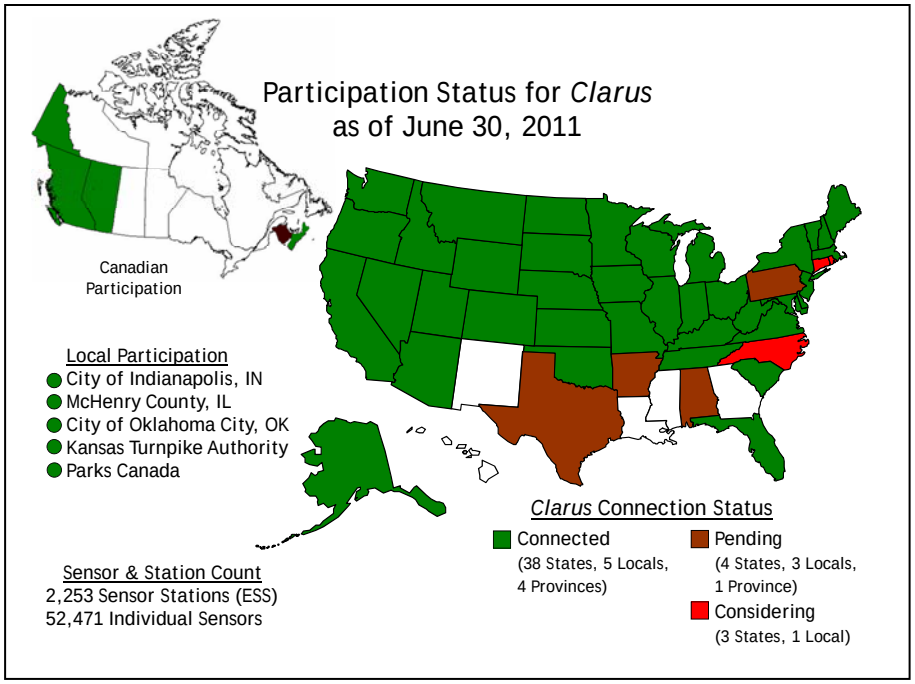
FHWA Road Weather Management Program

The FHWA coordinates a number of research and development activities aimed at improving safety, mobility, environmental quality, and national security on the nation's highways. These activities include identification and mitigation of weather impacts on the roadway environment. The FHWA does not operate either the highway or their supporting weather systems but seeks to improve operations in partnership with other public agencies, national laboratories, private firms, and universities. Since 1999, FHWA's weather-related research activities have been centered in the Road Weather Management Program (RWMP) within the Office of Transportation Operations in coordination with the Intelligent Transportation Systems (ITS) Joint Program Office.

With funding authorized under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) at nearly 5 million dollars per year, the goals of the RWMP are limited but span many areas to include: improve understanding of weather impacts on highway transportation systems, demonstrate a nation-wide system for observed road weather data, research new environmental data sources, enhance road weather (e.g. pavement temperature) and traffic modeling with weather inputs, enhance mechanisms for communicating road weather information to users, and develop decision support tools. For FY2011 and FY2012, RWMP major research projects include expanded road weather observed data management and decision support applications, weather and road data from vehicles or mobile devices (mobile data), and weather-responsive traffic management.

Road Weather Observing, Data Collection and Management – The *Clarus* System

Known as Environmental Sensor Stations (ESS), the standard method for observing road weather conditions is with fixed sensors near and/or actually embedded in the road surface that report common atmospheric weather variables plus pavement and subsurface road temperature, road wetness and pavement chemical concentration. Owned and operated by state, provincial or local transportation agencies, nearly 2,500 ESS are



deployed across North America and together comprise one of the largest weather observing networks.

Since 2006, a U.S. DOT-sponsored experimental system entitled *Clarus* (http://www.clarus-system.com/) has been collecting, formatting, quality checking, and displaying ESS road weather data from across North America. (*Clarus* Status Map) This "one-stop-shop" makes observed road weather more effectively shared by members of both the weather and the transportation communities. The long-term plan of the *Clarus* System is to transition the capability to the NWS. FHWA and NWS signed a memorandum of understanding (MOU) in November 2010 to establish a framework for cooperation and coordination for projects like the *Clarus* transition to operations. In FY2011, NWS and FHWA completed a system and requirements comparison of the *Clarus* System versus NOAA's Meteorological Assimilation Data Ingest System (MADIS). In FY 2011 and 2012, these agencies will collaborate to develop a transition plan. An important area of current research for both agencies is the gathering of weather and road data from vehicles.

USDOT Connected Vehicle Research – Vehicle Weather Observations

Connected Vehicles Research is a multimodal initiative that aims to enable safe, interoperable networked wireless communications among vehicles, the transportation infrastructure, and personal communication devices.[1] This research aims to leverage the potentially transformative capabilities of wireless technology to gather much more system data ultimately making surface transportation safer, smarter, and greener. Far beyond reliance on fixed or passive sensors, this emerging mobile technology has the potential to provide more extensive real-time travel and weather information to both the public sector and private industry.

Because vehicles were not designed as weather stations, direct weather sensor readings from original vehicle equipment are limited to mostly air temperature and pressure, but when combined with other vehicle data they could prove useful. Some of the inferred weather variables from vehicle data are precipitation rate, visibility, and road surface condition. The RWMP is currently working on a Vehicle Data Translator to process weather-related data from cars and trucks in order to better characterize the driving conditions along standard distance (e.g. one mile) or user-defined road segments.

In partnership with the National Center for Atmospheric Research (NCAR) and the states of Nevada and Minnesota, the FHWA began an expanded project in FY2010 to demonstrate how data already resident on state fleet vehicles may be collected, processed, transmitted and used for maintenance decision making in existing decision and management software tools. 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. Mobile weather and road condition data will also be integrated into the *Clarus* System. The vision is for both public and private decision-makers to have the benefit of decision support tools that are supported by data from millions of vehicles through the connected vehicle initiative.

[1] See http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm.

Road Weather Information Applications

Building on the successful prior work of a tool called the Maintenance Decision Support System, which provides winter maintenance recommendations (i.e., the mechanical removal of snow/ice (plowing) and/or application of chemical anti-icers or deicers), several projects in 2011 developed new road application and weather information services using *Clarus* System data from two multi-state regions across the western and mid-west US. These applications include enhanced road weather forecasting; a seasonal load restriction decision support tool; a non-winter maintenance and operations decision support tool; a multi-state control strategy tool; and enhanced road weather content for traveler advisories.

In FY 2012, five universities and three private companies under FHWA contract will complete their work to develop additional road weather tools and applications that further exploit *Clarus* System data. This research seeks to foster interdisciplinary collaboration, improve surface transportation weather management and operations, create innovative interfaces, and/or develop new applications. The eight projects focused on using *Clarus* System data are as follows:

- A Real-time Weather Responsive Traffic Signal System (University of Idaho)
- Improve weather information in the Regional Integrated Transportation Information System for the DC metropolitan area (University of Maryland)
- Passenger Bus Industry Weather Information Application (GST, Inc)
- Determination of Mobile Data Quality (UND)
- New Brunswick-Nova Scotia *Clarus* Integration Plus (AMEC, Ltd)
- One-Stop Shop For Rural Traveler Information (Western Transportation Institute)
- New York 511 Travel System Road Segment Alerting (Telvent, Inc)
- Integration of Weather and State Crash Data for a Travel Decision Support Tool (Michigan Technological University)

Note the passenger bus project will be accomplished by the same contractor that was awarded the National Mesonet Pilot and MoPED projects by the NWS. These cross-agency efforts have already shown great promise.

Weather Support for Traffic Managers

Unlike the national aviation system which has been a heavy user of weather information for decades, ground traffic management centers have been slow to integrate weather information. Since 2006, the RWMP focused a series of research projects on Weather-Responsive Traffic Management (WRTM) specifically addressing four areas: data collection and integration, human factors, WRTM strategies, and traffic analysis and modeling.

Initial research has been completed in many areas such as driver behavior in inclement weather; traffic speed and volume adjustment guidelines for various precipitation and visibility conditions; WRTM state of the practice review and concept of operations development, and message guidance for road weather advisory and control information.

The RWMP continues to work with several traffic management centers (TMCs) around the country using the FHWA Weather Integration Self-Evaluation Guide for TMC's. The guide steps the TMC through a self-assessment of its weather integration needs and identifies ways to improve the use of weather information in daily operations. In FY2012, the RWMP will begin a study to identify, develop, and test improvements to existing WRTM strategies. This task will also assess their benefits.

Only until the last few years have traffic models incorporated weather data or the effects of weather. The RWMP completed research on the integration of weather into several traffic models including dynamic traffic prediction and assignment systems. In FY 2012, validation should be complete for initial implementation and deployment to begin on a limited basis in some US cities. Research will also begin on the use of mobile weather data for traffic management

The FHWA will continue participation in several OFCM projects including the WIST Working Group and the Committee on Integrated Observing Systems (CIOS), among others. The FHWA is also participating in NOAA efforts to explore the development of a national mesonet system. Nearing the end of several research projects on data management and applications, the RWMP has begun to look at other problem areas and update the program's research agenda. For example, research has begun on the impact of weather on trucking, especially in the area of delay costs. The RWMP looks forward to building on past successes and partnering with organizations that share the same passion for reducing the impact of weather on the nation's road systems.

Federal Railroad Administration (FRA)

The FRA has outlined plans to support research on improving the collection, dissemination, and application of weather data to enhance railroad safety through its Intelligent Weather Systems project included in the FRA's 5-year Research and Development Strategic Plan. 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.

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.

Operationally, the FRA relies on the meteorological data streams coming for the National Weather Service's Storm Prediction Center when issuance of regulatory waivers to railroads during times of severe weather is necessary.

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. OSTEP is conducting a short-term anemometer study with USACE over FY11 and FY12 to explore a new technology for possible deployment at NWLON and PORTS® stations. Also, ongoing testing will reveal correlations of visibility data to other meteorological data types, and will result in a possible change in the standard sensor configuration of PORTS® visibility stations.

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 strengthened 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 (USFS) 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, the National Weather Service (NWS) in the National Oceanic and Atmospheric Administration (NOAA), 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 and Pacific Northwest GACC include 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 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 up to 8 days in advance. 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. These forecasters come from many different WFOs of all major NWS regions, and frequently support incidents more than a thousand miles from their home station. 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. They gather other weather information through a remote connection and provide stand-up and on-the-spot forecasts/analysis to firefighters and agency heads. 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 (known as the Wildland-Urban Interface or WUI). FY 2011 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 920 remote automated weather stations (RAWS) in a national network of over 2800 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 firefighting and for flash flood warnings. The RAWS Program oversees the standards for over 2800 remote automated weather stations across the country and manages the Interagency RAWS Website to support the program. The website address is http://raws.fam.nwcg.gov/. These stations form the basis for the assessment of fire danger, the pre-positioning of firefighting 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, under a contract with NWCG, was completed by the Desert Research Institute in FY 2011.

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.

Wildland fires in the wildland-urban interface are a continuing threat to lives and property.

The Wildland Fire Decision Support System (WFDSS) integrate emerging science and technology in support of risk-informed decision making. This system possesses many attributes that exclusively differentiate it from other wildland fire decision systems. It is a web-based system for documenting decisions, supporting analyses, and completing operational plans applicable to and used for all wildland fires. It promotes access to numerous information analysis tools in the areas of fire behavior modeling, fire weather information, economic principles, air quality and smoke management, and information technology to support effective wildland fire decisions consistent with Land and Resource Management Plans and Fire Management Plans. The WFDSS greatly reduces text input requirements by using spatially oriented and graphically displayed information. The system incorporates a progressive decision documentation and analysis process that can be scaled and adapted to match situational changes. Through WFDSS, information is assembled, consolidated, and processed for decision makers in a way that fosters collaboration

and, ultimately, provides better opportunities to improve large wildland fire strategic decision making.

U.S. Geological Survey (USGS)

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 NWS's 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 and Short-Term Fire Behavior components of the WFDSS use forecasted weather from the 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 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 FEMA and to State and local agencies. Since its inception, numerous advisories have been given to residents and public officials, resulting in saved lives and reduced property damage.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

Department of Agriculture, U.S. Forest Service

The research and development (R&D) mission of the USFS is to develop and deliver knowledge and innovative technology to improve the health and use of the Nation's forests and grasslands—both public and private. R&D provides this information to landowners, managers, policymakers,

and the American people to help inform their decisions and actions. USFS researchers work independently and with a range of partners to provide land managers with information and technology to make management and land use decisions on issues such as invasive species, healthy watersheds, wildfires, climate change, and traditional and alternative forest products. The USFS R&D workforce includes scientists and technicians in the biological, physical, and social science fields, working in partnership with researchers from other agencies, academia, nonprofit groups, and industry.

Air pollution effects (primarily nitrogen and sulfur deposition and ozone) remain a serious threat to forest health and aquatic systems in many parts of the U.S. Forest Service Research (FSR) is studying the long-term effects of air pollution on forests and water resources of the Sierra Nevada, Rocky Mountains in Colorado, the Appalachian Ridge in the east, and Cascades of the Pacific Northwest. Nitrogen and sulfur atmospheric deposition have been studied for many years in eastern forest watersheds, but these areas have only recently been studied. FSR has completed, in cooperation with the U.S. Environmental Protection Agency (EPA), NPS, National Forest System Air Program, and the European Union International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, a mock national assessment of critical loads of atmospheric deposition on ecosystems known to be sensitive to air pollution. Based on this experience FSR is working closely with other USFS collaborators and academic institutions to assess the uncertainty of these critical load measurements and to determine gaps in available data.

Smoke from forest fires and other biomass burning is a national concern as use of prescribed fire in ecosystem management increases. Exposure of fire fighters 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; the chemical nature of black carbon emissions from fire, and the potential of smoke to exacerbate particulate matter and ozone episodes. FSR has provided basic research to support State air regulatory programs and EPA's development of both primary and soon to come secondary air quality standards. Through 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. A key development in smoke and fire weather research products is the development of the WFDSS Air Quality Portal, which provides access to historic, real-time and forecasted air quality and meteorological information using a stand-alone web portal. Eight air quality and emissions tools provide information about the current smoke situation, climatological statistics, and weather forecasts. Five tools are available for immediate and short term smoke assessments. Two smoke guidance tools provide fire-specific tabular point forecasts and regional maps of air quality metrics.

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, USFS, NIFC, and the California Department of Forestry and Fire Protection 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.

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)

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. The KSCWO works with non-DOD sites and their weather service providers (such as the NWS or commercial companies) to provide similar assurance at those sites for NASA launches.

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 crlteria for lightning flight commit at commercial spaceports.

In FY 2011, the KSCWO conducted the following activities:

- Supported Space Shuttle missions: STS-133 through STS-135.
- Supported Space Shuttle Transition and Retirement (T&R).
- Supported the Constellation and its follow-on programs through infrastructure and requirements concept studies for the Space Launch System, Multipurpose Crew Vehicle (MPCV), 21st Century Ground Systems, and Orbital Flight Test 1.
- Completed formal publication and public distribution of 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.
- Supported infrastructure and concept of operations development for commercial launch programs and the NASA launch facility at Wallops Island, VA.
- Assisted the FAA in developing, finalizing, and implementing Lightning Flight Commit Criteria (14 CFR 417, Appendix G) for commercial spaceflight.
- Began updating the KSC on-line Weather Archive website (http://trmm.ksc.nasa.gov/).

In FY 2012, the KSCWO will perform the following activities:

- Continue to support the ELV and Space Shuttle T&R programs.
- Continue to support Wallops Island, Kodiak, and other launch facilities in addition to the DOD ranges.
- Continue to support commercial launch operators in developing weather infrastructure, requirements, and concepts of operation.
- Continue assisting the FAA with the development of Lightning Flight Commit Criteria for the commercial sector.
- 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.
- Complete the upgrade of the KSC Weather Archive website.

Spaceflight Meteorology Group

The SMG is located at JSC. In FY 2011, the SMG conducted the following activities:

- Supported Space Shuttle missions STS-133, STS-134, STS-135 with weather analyses, forecasts, briefings, consultations, and documentation.

- STS-135 was the last Shuttle mission for NASA. This concluded SMG support for the 30-year Shuttle program.
- 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.
- Provided consultation on the Orion Flight Test program, OFT1, being renamed as Multi-Purpose Crew Vehicle.
- Provided weather support and consultation for the HYTHIRM project based at NASA Langley for STS-133 and STS-134.
- Provided mentoring and training to several Southern Region NWS offices for developing local simulations.
- Upgraded AWIPS workstations to OB 9.2.12.
- Reduced staff per NASA's directive, in preparation for ending of Shuttle program.
- Supported several educational outreach events.

FY 2012 activities for the SMG include the following:

- Provide inputs and consultation for weather requirements for landing and recovery of the Orion MPCV spacecraft, focusing on Orion/MPCV Flight Test 1 (OFT1).
- Provide local hazardous weather support, including tropical storms and hurricane support to JSC Center Operations and to the International Space Station flight controllers.
- Upgrade AWIPS to AWIPS 2.
- Archive Shuttle weather history after the end of the Space Shuttle Program.
- Provide limited educational outreach.

Marshall Space Flight Center

The Natural Environments Branch (NEB) at MSFC develops and implements weather support requirements for the Space Shuttle and other programs, including development and evaluation of launch constraints.

FY 2011 activities of the NEB include the following:

- The NEB supported three Space Shuttle missions: STS-133 (24 February 2011), STS-134 (16 May 2011) and STS-135 (8 July 2011) 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.

Activities for FY 2012 include the following:

- The NEB will support the Space Launch System by developing and interpreting the terrestrial environment specifications, requirements, data, and models.
- The NEB will continue to develop and improve wind climatological data sets and models for future programs.

U.S. Air Force Space Launch Support

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

AFW at Patrick AFB, the Florida Air National Guard's 114th Range Operations Squadron directly supports the 45th Space Wing of the Air Force Space Command at both Patrick AFB and Cape Canaveral Air Force Station.

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 full suite of meteorological surface, upper air, satellite, radar, and lightning observing systems are available. Surface systems include an intra-atoll mesonet and an FAA-approved Automated Weather Observing System (AWOS III-P/T), supporting range and International Civil Aviation Organization Army Airfield operations at Kwajalein. Upper air sounding systems (1680 MHz), utilizing Global Positioning System (GPS) radio-sondes, are located on Kwajalein and Roi-Namur. One portable GPS upper air system (403 MHz) is available to

A rocketsonde launch on Kwajalein Atoll. U.S. Army Photo.

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 one geostationary satellite receiver provides 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. One thunderstorm sensor is attached to the AWOS III-P/T. RTS provides rocketsondes locally and at remote locations where radar tracking can support.

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)

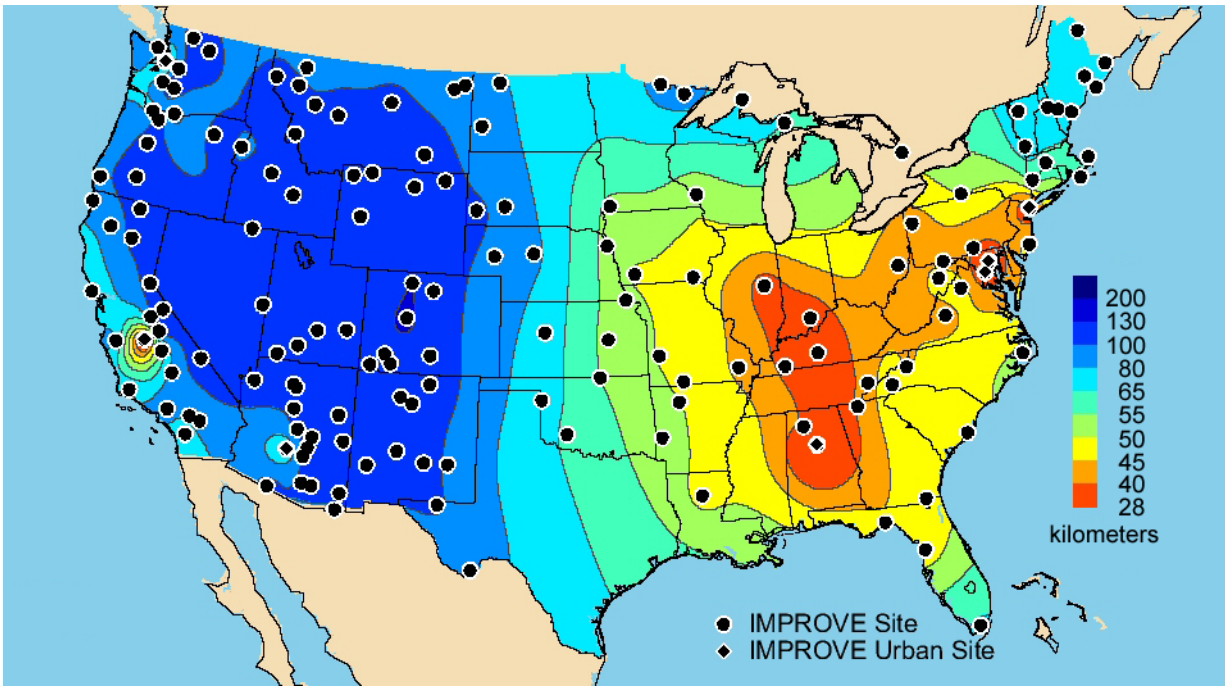
NPS Air Quality and Visibility Monitoring

NPS 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), NOAA, the U.S. Forest Service (USFS), the FWS, the Bureau of Land Management, 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.

Nuclear Regulatory Commission (NRC)

Assessments and evaluations of radiological impacts.

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. The NRC also maintains an interest in the effects of extreme meteorological events on the safe operation of nuclear facilities. 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.

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, and the NRC Regional Offices assure that NRC licensees comply with the regulatory requirements.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NASA

Applied Meteorology Unit

The Applied Meteorology Unit (AMU) is a joint venture between KSCWO, the USAF 45th Space Wing, and the NWS. The AMU is collocated with the 45th Weather Squadron located at CCAFS. The AMU develops, evaluates, and transitions weather technology into operations.

In FY 2011, the AMU performed the following activities:

- Updated 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 34. In addition, stratifications using Thompson Index for atmospheric stability and Precipitable Water for moisture were added to help operationally separate lightning days that are more active from those that are less active within the same flow regime.
- Conducted a Vandenberg Air Force Base (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 reviewed and analyzed the synoptic conditions for those days that winds at towers 70 and 71 met or exceeded the 35 knot warning threshold.
- Updated the MesoNAM verification by adding one year of data to the existing 3.5 year database and updated the GUI with the new statistics.
- Updated the Severe Weather Tool in MIDDS by adding the 2010 warm season data to increase the Period of Record to 22 years and use statistical logistic regression to develop a new forecast tool.
- Modified the Peak Wind Tool for User Weather Launch Commit Criteria cool season climatologies by adding 3 years of observations to increase the POR to 16 years and stratify the data by onshore/offshore flow rather than by month. Updated the Excel graphical user interface.
- Supported launch operations for three Space Shuttle, two Atlas V, three Delta IV, and one Falcon 9 missions.

In FY 2012:

- For FY 2012, the status of the AMU is unknown because funding for the AMU is still uncommitted at the time this is being written (4 August 2011). If the AMU is funded, this section of the KSC input will be supplemented with the FY 2012 plans.

Environmental Protection Agency

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 activities:

- 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 developing the national air quality standards, modeling guidelines, 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. As the concentration thresholds for the standards decrease, it will be important to understand intercontinental transport of pollution and how this would affect our ability to meet and maintain standards in the future. 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. Currently research is underway to test the efficacy of these models to accurately simulate the effects of aerosols on radiation.

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 and Gulf Coast, 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 roadway configuration, noise barriers, and vegetation on air quality near roadways are being assessed, and improvements are being made to the EPA's AERMOD 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 2011. It is also intended to serve as a community framework for continual advancement and for use in conducting environmental assessments. To this end, EPA has established a Community Modeling and Analysis System at the University of North Carolina in Chapel Hill, North Carolina, to provide user support and training to modelers at the state agencies and universities. CMAQ, configured for the Windows-NT computer system, is available on tapes from the National Technical Information Service. 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.

From FY 2005 to FY 2008, the EPA worked closely with the NWS National Centers for Environmental Prediction (NCEP) 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.

The EPA, through 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). The 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 NWS 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.

The 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.

National Park Service

NPS Air Quality Research

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.

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 were noted from source regions out of the state.

NPS is continuing this line of research in Grand Teton National Park in Wyoming, where some effects on aquatic ecosystems from nitrogen deposition have also been documented. A suite of field measurements of atmospheric reactive nitrogen was completed in 2011 and is currently being analyzed.

APPENDIX A
ACRONYMS

3DWF	3D [three dimensional] Wind Field [model]
4DWX	Four-Dimensional Weather System
AAWU	Alaska Aviation Weather Unit
ACC	[USAF] Air Combat Command
ACCESS	Advancing Collaborative Connections for Earth System Science
ACE	Advance Composition Explorer
AD	Active Duty
ADA	Air Domain Awareness
ADAS	AWOS Data Acquisition System
ADDS	Aviation Digital Data Service
AFB	Air Force Base
AFCENT	Air Force Central Command
AFI	Air Force Instruction
AFRC	Air Force Reserve Command
AFRI	Agriculture and Food Research Initiative
AFRL	Air Force Research Laboratory
AFW	Air Force Weather
AFWA	Air Force Weather Agency
AFWEPS	Air Force Weather Ensemble Prediction Suite
AFW-WEBS	Air Force Weather Web Services
AgriMet	[Bureau of Reclamation] Agricultural Weather
AHPS	Advanced Hydrologic Prediction Service
AIP	Airport Improvement Program [FAA]
AIRMoN	Atmospheric Integrated Research Monitoring Network
AMC	U.S. Army Materiel Command
AMS	American Meteorological Society; [FAA] Acquisition Management System; Autonomous Modular Sensor; Analysis and Modeling Subsystem
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	[Aqua satellite] Advanced Microwave Scanning Radiometer-E
AMU	Applied Meteorology Unit
ANG	Air National Guard
ANSP	Air Navigation Service Provider
AO	Announcement of Opportunity
AOC	[NOAA] Aircraft Operations Center
AOML	Atlantic Oceanographic and Meteorological Laboratory
AOR	Area of Responsibility
ARL	[NOAA] Air Resources Laboratory
ARM	Atmospheric Radiation Measurement Climate Research Facility
ARS	Agricultural Research Service

ARTCC	Air Route Traffic Control Center
ASCC	Army Service Component Commands
ASNE MSEA	[DOD] Air and Space Natural Environment Modeling and Simulation Executive Agent
ASOS	Automated Surface Observing System
ASR	Atmospheric System Research [activity in DOE/CESD]; Airport Surveillance Radar
ASR-11	Airport Surveillance Radar Model 11
ASR-9	Airport Surveillance Radar Model 9
ASWON	Automated Surface Weather Observation Network
ATCSCC	Air Traffic Control System Command Center
ATD	atmospheric transport and diffusion
ATDD	Atmospheric Turbulence and Diffusion Division [NOAA]
ATEC	U.S. Army Test and Evaluation Command
ATLAS	Autonomous Temperature Line Acquisition System
ATM	Air Traffic Management
ATO	Air Traffic Organization [FAA]
ATOP	Advanced Technologies and Oceanic Procedures
ATOS	Applications, Transactions, and Observations Subsystem
AWC	[NOAA/NECEP] Aviation Weather Center
AWG	Aviation Weather Group [FAA]
AWIPS	Advanced Weather Interactive Processing System
AWOS	Automated Weather Observing System
AWOS III-P/T	Automated Weather Observing System [variant of AWOS]
AWRP	Aviation Weather Research Program [FAA]
AWRT	Advanced Weather Radar Technique
AWSD	Aviation Weather Services Directorate
AWSS	Automated Weather Sensors Systems
BASC	Board on Atmospheric Sciences and Climate
BCTP	Battle Command Training Program
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BonD	Battlespace on Demand
CAC	[U.S. Army] Combined Arms Center
CAgM	[WMO] Commission for Agricultural Meteorology
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAP	Civil Air Patrol; Common Alerting Protocol
CASR	Committee for Aviation Services and Research
CBRNE	chemical, biological, radiological, nuclear, or explosive
CCAFS	Cape Canaveral Air Force Station
CCMC	Community Coordinated Modeling Center
CCSP	U.S. Climate Change Science Program
CDMP	Climate Database Modernization Program
CDR	climate data record

CEISC	Committee on Environmental Information Systems and Communications
CENR	[NSTC] Committee on Environment and Natural Resources
CENRS	[NSTC] Committee on Environment, Natural Resources, and Sustainability
CERIS	Coastal, Estuary Resource Information System
CESD	Climate and Environmental Sciences Division [DOE Office of Science]
CESM	Community Earth System Model
CESORN	Committee on Environmental Services, Operations, and Research Needs
CFC	chlorofluorocarbon
CFSR	Climate Forecast System Reanalysis
CHPS	Community Hydrologic Prediction System
CI-FLOW	Coastal-Inland Flood Observation and Warning
CICE	DOE/OS/CESD sea ice model
CICS	Cooperative Institute for Climate and Satellites
CICS-NC	Cooperative Institute for Climate and Satellites North Carolina
CIOS	Committee for Integrated Observing Systems
CIP	Current Icing Product
CISM	Community Ice Sheet Model (DOE/OS/CESD)
CJMTK	Commercial Joint Mapping Tool Kit
CLASS	Comprehensive Large-Array data Stewardship System
CLIVAR	Climate Variability and Predictability Experiment
CMAQ	Community Multi-scale Air Quality
CMAS	Commercial Mobile Alert System
CMD-P	Computer Meteorological Data-Profiler
CME	coronal mass ejection(s)
CMIP5	Coupled Model Intercomparison Project Phase 5
CMS	Carbon Monitoring System
CNMOC	Commander, Naval Meteorology and Oceanography Command
CNO	Chief of Naval Operations
COAMPS	Coupled Ocean/Atmosphere Mesoscale Prediction System
COASTAL	Coastal Oceanographic Applications and Services for Tides and Lakes
CoCoRaHS	Community Collaborative Rain, Hail, and Snow [network]
COLA	Center for Ocean-Land-Atmosphere Studies
COMNAVMETOCCOM	Naval Meteorology and Oceanography Command
CONPLAN	Concept of Operations Plan
COOP	Cooperative Observer Program
CO-OPS	Center for Operational Oceanographic Products and Services
COPC	Committee for Operational Processing Centers
CORMS	Continuous Operational Real-time Monitoring System
COSIM	Climate, Ocean and Sea Ice Modeling Project
COSMIC-2	Constellation Observing System for Meteorology Ionosphere and Climate-2
CPC	Climate Prediction Center
CPP	Command Post Platform
CSD	[NOAA/NWS] Climate Services Division
CSESMO	Committee for Space Environmental Sensor Mitigation Options

CVA	Ceiling and Visibility, Analysis [FAA/AWRP]
CVF	Ceiling and Visibility, Forecast [FAA/AWRP]
CWSU	Center Weather Service Unit
DAC	[AOML] Data Assembly Center; Department of the Army Civilian
DAPE	Data Acquisition, Processing, and Exchange
DASI	Digital Altimeter Setting Indicator
DATMS	Defense Information Switched Network Asynchronous Transfer Mode System
DEM	digital elevation model
DHS	U.S. Department of Homeland Security
DMCC	DOE Meteorological Coordinating Council
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
DOMSAT	domestic communication satellite
DOS	U.S. Department of State
DOT	U.S. Department of Transportation
DOTMLPF	doctrine, organization, training, materiel, leadership, education, personnel, and facilities
DPG	Dugway Proving Ground
DSCOVR	Deep Space Climate Observatory
DTC	Developmental Test Center; [U.S. Army] Developmental Test Command
DTRA	Defense Threat Reduction Agency
DTSS	Digital Topographic Support System
EAS	Emergency Alert System
EcoFOCI	Ecosystem-Fisheries Oceanography Coordinated Investigations
ECV	Essential Climate Variables
EdIWG	[CCSP] Education Interagency Working Group
ELV	Expendable Launch Vehicle(s)
EMC	[NOAA/NCEP] Environmental Modeling Center
EMI SIG	Emergency Management Issues Special Interest Group
EMSL	Environmental Molecular Sciences Laboratory
EOSDIS	Earth Observing System Data and Information System
EPA	U.S. Environmental Protection Agency
EPI	Enhanced Precipitation Identification
ERAM	En Route Automation Modernization
ERC	[hurricane] eyewall replacement cycles
ERDC	[USACE] Engineer Research and Development Center
EROS	[USGS] Earth Resources Observation and Science [center]
ESM	[DOE/OS/CESD] Earth System Models
ESRL	Earth System Research Laboratory
ESS	Environmental Sensor Station(s)

ESTP	[NASA] Earth Science Technology Program
ET	evapotranspiration
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration
FAR	false alarm rate
FCAMMS	Fire Consortia for Advanced Modeling of Meteorology and Smoke
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FEC	Fire Executive Council
FEMA	Federal Emergency Management Agency
FFMP	Flash Flood Monitoring and Prediction
FHWA	Federal Highway Administration
FIP	Forecast Icing Product
FMF	Fleet Marine Force
FNMOC	Navy Fleet Numerical Meteorology and Oceanography Center
FOR	Flight Operations Review
FPAW	Friends/Partners in Aviation Weather
FRA	Federal Railroad Administration
FRD	[NOAA/ARL] Field Research Division
FSR	Forest Service Research
FTE	full-time equivalent
FWS	U.S. Fish and Wildlife Service
FY	fiscal year
GACC	Geographic Area Coordinating Center
GBS	Global Broadcast Service
GCOS	Global Climate Observing System
GEOSS	Global Earth Observation System of Systems
GFDL	Geophysical Fluid Dynamics Laboratory [NOAA-associated]
GFDN	Geophysical Fluid Dynamics Navy [model]
GHCN-M	Global Historical Climatology Network-Monthly
GIS	geographic information system
GLD	Global Lagrangian Drifters
GLERL	Great Lakes Environmental Research Laboratory
GLOBE	Global Learning and Observations to Benefit the Environment
GMD	[NOAA/OAR/ESRL] Global Monitoring Division
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary Operational Environmental Satellite
GOES-R	Geostationary Operational Environmental Satellite R
GOOS	Global Ocean Observing System
GOSIC	Global Observing Systems Information Center
GPS	Global Positioning System
GPS-Met	GPS-Meteorology
GRA	GOOS Regional Alliances

GRIP	Genesis and Rapid Intensification Processes [NASA project]
GSD	[ESRL] Global Systems Division
GTGN	Graphical Turbulence Guidance Nowcast
GTOS	Global Terrestrial Observing System
GTS	Global Telecommunications System
HALE	high altitude, long-endurance [UAS]
HAZUS	Multi-Hazard Loss Estimation Methodology
HCFC	hydrochlorofluorocarbon
HEL	high-energy laser
HELSTF	High Energy Laser Systems Test Facility
HF	high frequency
HFIP	Hurricane Forecast Improvement Project
HFPP	HRD Field Program Plan
HHWWS	Heat Health Watch Warning Systems
HMR	[Nuclear Regulatory Commission] hydrometeorological report(s)
HMT	Hydrometeorological Testbed
HPC	[NPAA/NCEP] Hydrometeorological Prediction Center
HPCMP	[DOD] High Performance Computing Modernization Program
HQDA	Headquarters, Department of the Army
HRD	[NOAA/OMAO] Hurricane Research Division
HSPD	Homeland Security Presidential Directive
HWRF	Hurricane Weather Research and Forecasting
HYPOP	Hybrid Coordinate Parallel Ocean Program [DOE model]
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory [ATD model]
IBTrACS	International Best Track Archive for Climate Stewardship
ICAO	International Civil Aviation Organization
ICESCAPE	Impacts of Climate on Ecosystems and Chemistry of the Arctic Pacific Environment
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IFEX	Intensity Forecast Experiment
IHC	Interdepartmental Hurricane Conference
IIP	International Ice Patrol
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IMET	Incident Meteorologist
IMETS	Integrated Meteorological System
IMPROVE	Interagency Monitoring of Protected Visual Environments [program]
INL	Idaho National Laboratory
IPAWS	Integrated Public Alert and Warning System
IPB	intelligence preparation of the battlespace
IPCC	Intergovernmental Panel on Climate Change
IPE	intelligence preparation of the environment
IRTSS	Infrared Target Scene Simulator

ISCS	International Satellite Communications System
ISES	International Space Environment Service
ISMS	[DOE] Integrated Safety Management System
ISR	intelligence, surveillance, and reconnaissance
ISS	International Space Station
IT	information technology
IT R&D	Information Technology Research and Development [Program]
ITS	Intelligent Transportation Systems
ITWS	Integrated Terminal Weather System
IWEDA	Integrated Weather Decision Aid
IWGCCST	Interagency Working Group on Climate Change Science and Technology
IWRSS	Integrated Water Resources Science and Services
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/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
JAWS	Juneau Airport Wind System
JCIDS	Joint Capabilities Integration and Development System
JCSDA	Joint Center for Satellite Data Assimilation
JHT	Joint Hurricane Testbed
JPDO	Joint Planning and Development Office
JPSS	Joint Polar Satellite System
JSC	[NASA] Johnson Space Center
JTWC	Joint Typhoon Warning Center
KDP	Key Decision Point
KSC	[NASA] Kennedy Space Center
KSCWO	SOMD Weather Office at NASA Kennedy Space Center
LAN	local area network
LAP	Lightning Advisory Panel
LBS	Littoral Battlespace Sensing
LDCM	Landsat Data Continuity Mission
LIDAR	light detection and ranging
LLCC	lightning launch commit criteria
LLWAS	Low Level Wind shear Alerting System
LLWAS-NE	LLWAS Network Expansion
LRGS	[USGS] local readout ground station(s)

M&O	management and operating
MACPEX	Mid-latitude Airborne Cirrus Properties Experiment
MADA	Monsoon Area Drought Atlas
MADIS	Meteorological Assimilation Data Ingest System
MAGTF	Marine Air Ground Task Force
MALE	medium altitude, long endurance [UAS]
MASPS	Minimum Aviation Safety Performance Standards
MAW	Marine Aircraft Wing
MEF	Marine Expeditionary Force
MET	meteorological; Meteorology and Oceanography
MetMF(R)	Meteorological Mobile Facility-Replacement
METOC	meteorological and oceanographic
METOP	Meteorological Operational Polar
METSAT	meteorological satellite
MM5	Mesoscale Model Version 5
MMS-P	Meteorological Measurement Set-Profiler
MOC	[NextGen] Mid-term Operational Capability
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPS	Minimum Operations Standards
MOU	memorandum of understanding
MPAR	multifunction phased array radar
MPCV	Multipurpose Crew Vehicle
MRMS	[FAA/AWRP] Multi-Radar Multi-Sensor [capability]
MSFC	Marshall Space Flight Center
MST	METOC Support Team
MTOE	Modified Table of Organization and Equipment
MTSAT	[Japanese] Multifunctional Transport Satellite
MWPI	Microburst Windspeed Potential Index
MWSG	Marine Wing Support Group
MWSS	Marine Wing Support Squadron
NADM	North American Drought Monitor
NADP	National Atmospheric Deposition Program
NAO	NOAA Administrative Order
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NAVOCEANO	Naval Oceanographic Office
NAVOCEANOPSCOM	Naval Oceanography Operations Command
NBC	nuclear, biological, and chemical
NCA	National Climate Assessment
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction

NCOM	Navy Coastal Ocean Model
NCV	National Ceiling and Visibility [FAA/AWRP Product Team]
NDBC	National Data Buoy Center
NDFD	National Digital Forecast Database
NDMC	National Drought Mitigation Center
NEB	Natural Environments Branch [MSFC]
NESDIS	[NOAA] National Environmental Satellite, Data, and Information Service
NEXION	NEXt-generation IONosonde
NEXRAD	Next-Generation Weather Radar
NextGen	Next Generation Air Transportation System
NFDRS	National Fire Danger Rating System
NFIP	National Flood Insurance Program
NGA	National Geospatial-Intelligence Agency
NGDC	National Geophysical Date Center
NGEE	Next-Generation Ecosystem Experiments
NHC	[NCEP] National Hurricane Center
NICC	National Interagency Coordination Center
NIDIS	National Integrated Drought Information System
NIFA	National Institute for Food and Agriculture
NIFC	National Interagency Fire Center
NITES	Navy Integrated Tactical Environmental System
NNEW	NextGen Network Enabled Weathe
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NOCMP	National Operational Coastal Modeling Program
NODC	National Oceanographic Data Center
NOGAPS	Navy Operational Global Atmospheric Prediction System
NOHRSC	National Operational Hydrologic Remote Sensing Center
NOMADS	National Operational Model Archive and Distribution System
NOP	Naval Oceanography Program
NOPC	National Operational Processing Centers Program Council
NORAD	North American Aerospace Defense Command
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
NPS	National Park Service
NRC	Nuclear Regulatory Commission; National Research Council
NRCC	[FEMA] National Response Coordination Center
NRCS	Natural Resources Conservation Service
NRL	Naval Research Laboratory
NRL/MRY	Marine Meteorology Division of the Naval Research Laboratory [NRL Monterey]

NSF	National Science Foundation
NSIP	National Streamflow Information Program
NSIR	Office of Nuclear Security and Incident Response
NSPD	National Security Presidential Directive
NSSL	[NOAA] National Severe Storm Laboratory
NSWP	National Space Weather Program
NSWRC	NextGen Surveillance and Weather Radar Capability
NTAS	Northwest Tropical Atlantic Station
NTHMP	National Tsunami Hazard Mitigation Program
NUOPC	National Unified Operational Prediction Capability
NWCG	National Wildfire Coordinating Group
NWIS	National Water Information System
NWLON	National Water Level Observation Network
NWP	numerical weather prediction
NWR	NOAA Weather Radio
NWRT	National Weather Radar Testbed
NWS	[NOAA] National Weather Service
OAR	[NOAA] Office of Atmospheric Research
OCE	(USDA) Office of the Chief Economist
ODCS	[U.S. Army] Office of the Deputy Chief of Staff
OEP	Operational Evolution Partnership [FAA airport designation]
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
ONR	Office of Naval Research
OPC	Ocean Prediction Center
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
OTSR	Optimum Track Ship Routing
OWS	[USAF] Operational Weather Squadron
P3I	Pre-Planned Product Improvement
PACAF	Pacific Air Forces
PARISE	Phased Array Radar Innovative Sensing Experiment
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PLAN	Personal Localized Alert Network
PMEL	Pacific Marine Environmental Laboratory
PNE	PIRATA Northeast Extension [project]
POD	probability of detection

POES	Polar-orbiting Operational Environmental Satellite
POP	Parallel Ocean Program [DOE/OS/CESD model]
POPS	Primary Oceanographic Prediction System
PORTS®	Physical Oceanographic Real-Time System
PREDICT	Pre-Depression Investigation of Cloud-systems in the Tropics
PSD	[ESRL] Physical Sciences Division
PTWC	Pacific Tsunami Warning Center
QPE	quantitative precipitation estimation(s)
QPF	quantitative precipitation forecast
R&D	research and development
R2O	Research to Operations
RASCAL	Radiological Assessment System for Consequence Analysis
RAWS	Remote Automated Weather Stations (network)
RBSP	Ring Current, Radiation Belts, Solar Particles [satellite]
RDT&E	research development, test, and evaluation
RES	Office of Nuclear Regulatory Research
RFC	[NWS] River Forecast Center
RGCM	Regional and Global Climate Modeling [in DOE/OS/CESD]
RIMS	Radio Interference Measuring Set
ROMANS	Rocky Mountain Atmospheric Nitrogen and Sulfur
ROSES	[NASA] Research Opportunities in Space and Earth Sciences
RPA	Remotely Piloted Aircraft
RSMC	Regional Specialized Meteorological Center
RSTN	Radio Solar Telescope Network
RTC	Redstone Test Center
RTS	Ronald Reagan Ballistic Missile Defense Test Site
RTVS	Real-Time Verification System
RUC	Rapid Update Cycle [NWS forecast model]
RVR	Runway Visual Range
RWI	Reduce Weather Impact
RWMP	Road Weather Management Program
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SAS	[NextGen] Single Authoritative Source
SAWS	Stand Alone Weather Sensors [FAA]
SCAN	Soil Climate Analysis Network
SCAP	Security Certification and Accreditation Package
SCAPA	Subcommittee for Consequence Assessment and Protective Actions
SDO	Solar Dynamics Observatory
SDR	[CENRS] Subcommittee on Disaster Reduction
SEBN	Surface Energy Budget Network
SEES	Science, Engineering and Education for Sustainability

SEON	Solar Electro-optical Observing Network
SERVIR	Sistema Regional de Visualizacion y Monitoreo [NASA network]
SESAR	Single European Sky ATM Research
SFMR	stepped frequency microwave radiometer
SGOT	Strike Group Oceanography Team
SICPS	Standard Integrated Command Post Shelter
SIP	Societal Impacts Program
SIR	System Integration Review
SLEP	Service Life Extension Program
SLOSH	Sea, Lake and Overland Surges from Hurricanes [storm surge model]
SMAP	[NASA] Soil Moisture Active-Passive [Satellite Mission]
SMD	[NASA] Science Mission Directorate
SMDC	[U.S. Army] Space and Missile Defense Command
SMG	[NWS] Spaceflight Meteorology Group
SNOTEL	SNOw pack TELemetry
SOF	Special Operations Forces
SOHO	Solar and Heliospheric Observatory
SOMD	[NASA] Space Operations Mission Directorate
SOON	Solar Observing Optical Network
SOOP	Ship of Opportunity Program
SORD	[NOAA/ARL] Special Operations and Research Division
SPC	[NCEP] Storm Prediction Center
SRS	Solar Radio Spectrograph
SST	sea surface temperature
SSWSF	Snow Survey and Water Supply Forecasting Program
STAR	Center for Satellite Applications and Research
STEM	Science, Technology, Engineering, and Mathematics
STEREO	Solar Terrestrial Relations Observatory
STIWG	Satellite Telemetry Interagency Working Group
SWEF	Space Weather Enterprise Forum
SWIM	[NextGen] System Wide Information Management
SWPC	Space Weather Prediction Center
SWSI	State Surface Water Supply Index(es)
TAF	Terminal Aerodrome Forecast
TAO	Tropical Atmosphere-Ocean [Project]
TAO/TRITON	Tropical Atmosphere-Ocean/TRIangle Trans-Ocean buoy Network
TAWS	Target Acquisition Weapons Software
TDA	Tactical Decision Aid
TDWR	Terminal Doppler Weather Radar
TFCC	Task Force Climate Change
T-IWEDA	Tri-Service Integrated Weather Effects Decision Aid
TMC	traffic management center
TOC	Tactical Operations Center

TOE	Table of Organization and Equipment
TRADOC	U.S. Army Training and Doctrine Command
TRMM	Tropical Rainfall Measuring Mission
TSG	thermosalinograph
TSO	Technical Standard Order [FAA]
UAS	unmanned aircraft systems; unmanned aerial systems
UHF	ultrahigh frequency
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNOLS	University-National Oceanographic Laboratory System
UNSWC	Unified National Space Weather Capability
URI	University of Rhode Island
USA	U.S. Army
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USAICoE	U.S. Army Intelligence Center of Excellence
USARNORTH	U. S. Army North
USASMDC	U.S. Army Space and Missile Defense Command
USCG	U.S. Coast Guard
USCRN	U.S. Climate Reference Network
USDA	U.S. Department of Agriculture
USDM	U.S. Drought Monitor
USFF	U.S. Fleet Forces Command
USFS	U.S. Forest Service
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
USHCN	U.S. Historical Climatology Network
USNO	U.S. Naval Observatory
USNORTHCOM	U.S. Northern Command
USWRP	U.S. Weather Research Program
UV	ultraviolet
VAAC	Volcanic Ash Advisory Center
VAFB	Vandenberg Air Force Base
VFR	visual flight rules
VORTEX2	Verification of the Origins of Rotation in Tornadoes Experiment 2
VOS	Volunteer Observing System
WAFS	World Area Forecast System
WAMIS	World AgroMeteorological Information Service
WAOB	World Agricultural Outlook Board
WARP	Weather And Radar Processor [FAA]
WASDE	*World Agricultural Supply and Demand Estimates* [report]

WC/ATWC	West Coast/Alaska Tsunami Warning Center
WEBB	Water, Energy, and Biogeochemical Budgets
WFDSS	Wildland Fire Decision Support System
WFIP	Wind Forecast Improvement Project
WFO	National Weather Service Forecast Office
WG/DIAP	Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (
WG/TBC	Working Group for Test Bed Coordination
WG/UM	Working Group for Urban Meteorology
WG/VA	Working Group on Volcanic Ash
WG/WIST	Working Group on Weather Information for Surface Transportation
WGA	Western Governors' Association
WHDE	Wind Hazard Detection Equipment
WIFS	WAFS Internet File Service
WIMS	weather information management system
WIS	WMO Information Service
WMO	World Meteorological Organization
WoF	Warn on Forecast [Program]
WP	Work Product
WRAP	Wildfire Research and Applications Partnership
WRD	[USGS] Water Resources Discipline
WRE-N	Weather Running Estimate-Nowcasts
WRF	Weather Research and Forecasting
WRTM	Weather-Responsive Traffic Management
WS	[USAF] Weather Squadron
WSDS	Wind Shear Detection Services
WSP	[FAA] Weather Systems Processor
WSR-88D	Weather Surveillance Radar-1988 Doppler
WTIC	Weather Technology in the Cockpit
WUI	Wildland-Urban Interface
WW3	Wave Watch III [model]
WWCB	*Weekly Weather and Crop Bulletin*
WWLLN	World Wide Lightning Locator Network
WXG	[USAF] Weather Group
XBT	Expendable BathyThermograph [Program]