# The Federal Plan for Meteorological Services and Supporting Research

# Fiscal Year 2013

OFCM

OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH

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

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Meteorological Services and Supporting Research

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FEDERAL COORDINATOR FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

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Lead Editor Mr. Anthony Ramirez
Assistant: Ms. Erin McNamara
Assistant: Mr. Kenneth Barnett

# PREFACE

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

The FY 2013 Federal Plan uses the structure first introduced in the FY 2011 Plan. Section 1 summarizes the resources appropriated by Congress for FY 2012 and the resources requested in the President's FY 2013 Budget. Please note that actual FY 2012 funding under continuing resolutions or the eventual final appropriation is not described in Section 1. The budget narrative is organized by agency, and tables 4 and 5 provide a breakdown by major service category for the purposes of cross-agency coordination and cooperation. Section 2 contains narratives, by service category, describing agency operations and programs for providing meteorological services and supporting research and development. This organization by service category, 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 the OFCM. This segment replaces and expands on the appendix describing OFCM activities that were 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.

Over the last several years, there has been a marked increase in the operational program and supporting research information included in the narratives submitted by the agencies. This has certainly made the Federal Plan even more comprehensive, informative, and useful. My thanks to our agency partners and their staffs for their dedicated and outstanding efforts which have significantly contributed to this vitally important document.

**//SIGNED//**

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

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# 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) 2012 and 2013. 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 2012 and are subject to later changes. The data for FY 2013 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

The Department of Agriculture's (USDA) budget request for FY 2013 is $62.1 million for operations and supporting research, down 4 percent from the FY 2012 funding level. The decrease in funding is mainly for research programs, with only a slight increase in funding requested for meteorological operations. USDA has requested $43.1 million for research and development programs, a $2.9 million decrease from 2012. Most of the funding decrease is for the National Institute of Food and Agriculture (NIFA), due to the completion of some integrated mandatory programs and elimination of other research programs with a weather and climate component. 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. The Agricultural Research Service (ARS) is the USDA's principal in-house scientific research agency. ARS conducts research on how annual variation in weather adversely effects crop and animal production, hydrologic processes, the availability of water from watersheds, and the environmental and economic sustainability of agricultural enterprises. The research and development mission of the Forest Service is to develop and deliver knowledge and innovative technology to improve the health and use of the Nation's forests and grasslands. Research at the Forest Service includes studies of the long-term effects of air pollution on forests and water resources. The Forest Service is also the world leader in developing emissions factors from fires and modeling its dispersion.

The FY 2013 amount requested for meteorological operations is $19.0 million, slightly up from the $18.9 million funding level in FY 2012. Operational activities include specialized weather observing

networks such as the SNOTEL (SNOw pack TELemetry) network operated by the Natural Resources Conservation Service (NRCS) Snow Survey and Water Supply Forecasting program (SSWSF) 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 SSWSF program, managed by the NRCS National Water and Climate Center, provides western states and Alaska with information on future water supplies. The Forest Service uses meteorological data and interpretation skills data for decision making regarding wildland fire management. 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. JAWF is actively involved in drought monitoring efforts in concert with the National Drought Mitigation Center.

## DEPARTMENT OF COMMERCE/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The Department of Commerce (DOC) submitted a realignment plan subsequent to the submission of the FY 2013 President's Budget Request to Congress. This realignment of funding, referred to as the FY 2013 President's Budget with Reallocation, is a net zero sum gain to reallocate funds for costs associated with critical weather forecasting activities. These changes adhere to the guiding principle to protect life and property by sustaining warning and forecast capabilities of the NWS and, where necessary, delay future improvements to services. All Department activities and funding reported here reflect the NOAA FY 2013 reallocation of funds.

### National Weather Service

The National Weather Service (NWS) funding request for the FY 2013 President's Budget totals $976.4 million and 4,544 full-time equivalent (FTE) employees. Significant requested increases and decreases in funding over the FY 2012 program include the following:

- ***Ground Readiness Project.*** National Oceanic and Atmospheric Administration (NOAA) requests an increase of $9.4 million to ensure utilization of the substantial increase in environmental satellite observations that will help to improve weather warnings and forecasts. This investment will increase NWS information technology infrastructure capacity to ensure processing of the three-fold data volume increase expected from satellite and radar observations, and advanced weather prediction models coming online from FY 2013-2017, improving weather warnings and forecasts accuracy.
- ***NWS Telecommunications Gateway (NWSTG) Legacy Replacement.*** NOAA requests an increase of $7.0 million to design and implement a re-architected NWSTG and it's backup to accommodate future data volumes driven by increased climate and satellite observations and other requirements, and to maintain system reliability. This investment will allow the NWS to transform the Telecommunications Gateway (NWSTG) and its backup into a modern, scalable, extensible, and reliable system. The NWSTG is a hub for collection and transmission of hydrometeorological observations and products for NOAA's customers.

- ***Tropical Atmosphere Ocean (TAO) Array.*** NOAA requests an increase of $2.4 million to support operations and maintenance (O&M), and technology refresh costs associated with the TAO buoys, to achieve an 80% data availability standard. TAO network data directly contributes to the accurate prediction of El Niño and La Niña climate events and enables mitigation of impacts.
- ***Regional Information Technology (IT) Collaboration Units.*** NOAA requests a decrease of 98 FTE and $9.7 million to reflect the transition to a new IT service delivery model to the NWS forecast offices. This decrease will create regional information technology collaboration teams enabling higher consistency of service delivery with minimal impacts to NWS' mission. NWS will downsize the current 122 IT Officers to 24 regional collaboration units. NWS has the ability to fulfill much of the ITO responsibilities remotely.
- ***Strengthen U.S. Tsunami Warning Network.*** NOAA requests a decrease of $4.5 million to terminate NOAA's partner funding for education and awareness programs to the National Tsunami Hazard Mitigation Program (NTHMP) within the Strengthen U.S. Tsunami Warning Program (SUSTWP) and reduces funding for maintenance of the Deep-ocean Assessment and Reporting Tsunamis buoy network. NOAA will continue to educate the public about tsunamis through the TsunamiReady program. Timely issuance of tsunami warnings will continue, but warnings may extend to a larger area and for a longer time.
- ***NOAA Profiler Network and Conversion (NPN).*** NOAA requests a decrease of $.1 million in its NOAA Profiler Network (NPN) Program to terminate its NPN array except operations and maintenance support of three profilers located in Alaska. Three profilers located in Alaska will provide information critical for specialized aviation and volcanic ash forecasts. The increasing cost of modernizing profilers requires NOAA to terminate the broadcast frequency conversion and technology refreshment and discontinue operation of the other 32 profilers.
- ***Air Quality Forecasting.*** NOAA requests a decrease of $3.1 million to discontinue the National Air Quality Forecasting Capability (NAQFC) which is used by the Environmental Protection Agency and state and local agencies to provide public air quality health alerts. Remaining funding will sustain on-demand dispersion forecasts of volcanic ash, transport of smoke, and forecast of emergency releases, supporting aviation affected by volcanic activity.
- ***Labor and Operations.*** NOAA requests an increase of $17.1 million to fully fund labor costs required in FY 2013. This increase protects NOAA's life and property mission by sustaining forecast and warning capabilities.
- ***NOAA Weather Radio.*** NOAA requests a decrease of $1.5 for deferment of improvements to current NOAA Weather Radio (NWR) services. This decrease will defer replacement of analog transmitters with digital versions.
- ***Advanced Weather Interactive Processing System (AWIPS).*** NOAA requests a decrease of $2.4 million resulting in an extension of the AWIPS technology infusion program schedule. AWIPS communications infrastructure enables NWS forecasters to effectively use technology investments such as observing systems data and models along with decision assistance tools to develop and deliver weather warnings and forecasts. NWS will continue to focus on the highest priority projects including enabling remote access to AWIPS products by incident meteorologists who support state and local emergency managers.

### National Environmental Satellite, Data, and Information Services

NOAA/National Environmental Satellite, Data, and Information Services (NESDIS) requests a net increase of $162.361 million for a total of $2.040 billion and 818 FTEs for the FY 2013.

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 2013:

- Polar Operational Environmental Satellite Systems (POES) NOAA Polar K-N' (Base Funding: 22 FTEs and $32.241 million). NOAA requests no change from the FY13 Base Funding for a total of $32.241 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 $949.894 million). NOAA requests a decrease of 33.5 million and 0 FTE for a total of $916.364 million 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.

- In FY 2013, JPSS Program also includes the funding for Restoration of Climate Sensors previously funded separately in earlier budget years. Restoration of Climate Sensors continues the 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). 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.

- Jason-3 (Base Funding: 0 FTEs and $19.700 million). NOAA requests an increase of $10.3 million for a total of $30.0 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: 20 FTEs and $32.467 million). NOAA requests a decrease of $2.567 million for a total of $29.900 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 $615.622 million). NOAA requests an increase of $186.378 million for a total of $802.0 million to provide continued satellite engineering development and production activities for the GOES-R Series (GOES-R, -S, -T, & U) program that are necessary to meet a Q1 FY2016 launch readiness date (LRD).

- Deep Space Climate Observatory (DSCOVR) (Base Funding: 0 FTE and $29.800). NOAA requests a decrease of $6.917 million in FY 2013 to continue the refurbishment of DSCOVR, which will provide solar wind data for geomagnetic storm warnings.

- FY 2013 funds will support the continued refurbishment of an existing NASA Satellite, DSCOVR, by the NASA/Goddard Space Flight Center (GSFC). This program is in partnership with the U.S. Air Force (USAF), which will provide the launch vehicle and services. The lifecycle cost of $85 million will provide for the development and operation of systems for solar wind data processing and distribution, calibration and validation, and data archiving. After launch, NOAA will be responsible for command and control of the satellite, as well as timely processing and distribution of the solar wind data for geomagnetic storm warnings.

### Office of Oceanic and Atmospheric Research

The Office of Oceanic and Atmospheric Research (OAR) request for funding related to meteorological supporting research in the FY 2013 President's Budget totals $120 million and 459 full-time equivalent (FTE) employees.

Requested FY 2013 funding for Weather and Air Chemistry Research (W&ACR), including Laboratories and Cooperative Institutes and Weather and Air Chemistry Research Programs is $67.0 million. This amount represents a net decrease of $0.7 million or 1% percent from the FY 2012 spend plan. Decreases of $0.7 million would be spread across the Unmanned Aircraft Systems Program, Cooperative Institutes, and U.S. Weather Research Program. OAR's Weather and Air Chemistry Research supports R&D that provides the Nation with more accurate and timely warnings and forecasts of high impact weather events and their broader impact on issues of societal concern such as weather and air quality; and supports research that provides the scientific basis for informed management decisions about weather, water, and air quality.

Requested FY 2013 funding for Climate Labs and Cooperative Institutes is $53.4 million. This amount represents a net increase of $ 1.3 million or 2.5% from the FY 2012 spend plan. Increases of $1.3 million consist of funds to partially cover inflationary cost increases within base programs ($1.1

million) and to continue research activities within its Laboratories and Cooperative institutes for monitoring and understanding the Earth's climate system and to predict both the potential long-term changes in global climate as well as shorter-term climate variations that are of societal and economic importance ($0.2 million).

### National Ocean Service

$29.0M provided through the FY 2013 budget will allow for continued operation of the National Water Level Observation Network (NWLON), expansion of the Physical Oceanographic Real-Time System (PORTS®) program, improvement of the 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. In 2011, National Ocean Service (NOS) added visibility as another sensor option for PORTS®. At this time the only operational NOS visibility sensors are in Mobile Bay, AL. 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. Actual verification data for special marine warnings (WFO Sterling) shows a 10% increase in the probability of detection and a ten minute increase in warning lead times, due in part to an increase in marine observations. Navigation data users require a complete picture of their operating environment to make the best safety and efficiency decisions, and local meteorological data is a part of that picture. Optimization of existing observing infrastructure is a cost-effective alternative to establishing new platforms. The additional meteorological data improves 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

The Office of Marine and Aviation Operations (OMAO) supports meteorological activities by collection of related data from ships and aircraft. The FY 2013 Reallocation President's Budget request of $29.741 million represents a 4.6 percent increase from the FY 2012 appropriation and maintains OMAO's ship and aircraft support of meteorological data collection.

## DEPARTMENT OF DEFENSE

### U.S. Air Force/Air Force Weather Agency

U.S. Air Force (USAF) resources for meteorological support fall into two primary categories: general

operations and investment and research. The total Air Force Weather Agency (AFWA) weather operations and research funding requested for FY 2013 is $136.5 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 2013 budget is $107.4 million and funds day-to-day environmental support to the Department of Defense, 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 1,157 military and civilian personnel to conduct these activities at more than 23 locations worldwide. Approximately 85 percent of personnel specialize in weather; the remainder includes communications, computer, information technology, program management, program analysis, administrative, and logistics specialists.

### Supporting Research

The total AFWA budget for meteorological-related research during FY 2013 is $29.0 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 2013 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.

### U.S. Navy

The U.S. Navy (USN) FY 2012 budget allocation for meteorological programs was $79.3 million; made up of $69.8 million for operations and $9.5 million to support enabling research. These numbers increase in FY 2013 to $84.5 M, $74.7 M, and $9.88 M respectively.

#### Naval Oceanography Program

The Chief of Naval Operations, through the Oceanographer of the Navy, sponsors operational Navy METOC services and related research and development. In 2012, the Oceanographer of the Navy acquired responsibility for funding the Navy's meteorology and oceanography Operations & Maintenance (O&M, N) funding from the Chief of Naval Operations (N43).

The Navy provides meteorological services for Navy and joint forces, meteorological products to the Marine Corps, and oceanographic support to all elements of the Department of Defense, as well as to allied and coalition partners. The Navy 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. The Oceanographer of the Navy is also the Director of Oceanography, Space, and Maritime Domain Awareness for the Navy. Naval METOC personnel (Navy and Marine Corps) are required to provide intelligence preparation of the operational environment (IPOE) for 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 Naval Oceanography Program (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. 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 provides a wide array of essential tactical, operational and strategic METOC products and services to operating forces afloat and ashore. These services include collecting and processing environmental data using resources such as oceanographic ships, aircraft, satellites, and computing systems. These products and services enhance the performance of active and passive sensor and weapon systems; optimize the effectiveness of the sea control mission for mine counter-measures; and identify the environmental effects that influence the performance of fixed and mobile warfare systems and tactics. General and tailored oceanographic, acoustic, and meteorological forecasts are provided daily to fleet commanders and individual operating units from the Meteorology and Oceanography Command's numerical modeling and forecasting centers and from forecasting support activities located worldwide. Funding primarily supports national security interests and also benefits maritime commerce. 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. This funds new and replacement meteorological equipment for all Navy and Marine Corps Air Stations, all Navy ships, USMC Operational Forces units and other activities required to provide weather observations and provides safety of flight capabilities. The procurement has been thoroughly coordinated with other DoD and civilian agencies. Program also funds replacement of Survey Vessel shipboard mission equipment, deep and multibeam SONARs, Side Scan SONARs, Hydrographic Survey Launches, Ship Moving Vessel Profilers, Unmanned Under Water Gliders, and Autonomous Underwater Vehicles. The Oceanographer of the Navy also funded, through its SCN, two new research vessels (one in FY 2011; one in FY 2012), to be operated by civilian research institutions in coordination with the University National Oceanographic Laboratory System (UNOLS).

***Navy Integrated Tactical Environmental System (NITES-Fielded, NITES-Next).*** 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

Naval METOC R&D is cooperatively sponsored by the Oceanographer/Navigator of the Navy and the Chief of Naval Research. This program enables the warfighter of the future to effectively carry out their mission by transitioning to operational use research performed by the Office of Naval Research. The Space and Naval Warfare Systems Command is the primary office responsible for transitioning Naval research to operational use. All research and development funded by the Oceanographer of the Navy is in direct support of the Naval mission.

Naval Research and Development (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.

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

The U.S. Army (USA) estimates a $23.9 million requirement for operational support and $13.8 million requirement for research and development in FY 2013. Funding for operational support will increase by 33 percent while funding for research increases slightly from FY 2012 to FY 2013. Staffing levels remain relatively stable with a slight increase for FY 2013. The 33 percent increase in FY2013 operational funding can be traced to an additional $6.9 million to field the Artillery's Profiler Block III systems.

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 coordination of meteorological support within the Department of the Army and with other DoD 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 United States Air Force 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. As part of the TRADOC weather support structure, the U.S. Army Intelligence Center of Excellence (USAICoE) employs one meteorologist to lead USAICoE weather proponent efforts in the Joint Capabilities Integration and Development System (JCIDS) process and in doctrine, organization, training, materiel, leadership, education, personnel, and facilities (DOTMLPF) work. This JCIDS and DOTMLPF work occur within USAICoE and in conjunction with other USA Centers of Excellence and the Army research and experimentation organizations.

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, including weather, across all echelons. DCGS-A weather services enable the Staff Weather Officer and intelligence operators to analyze and mitigate weather effects on intelligence operations, target development, and course of action selection. DCGS-A provides the actionable weather intelligence in support of tactical Army operations as well as resource protection. DCGS-A weather applications take advantage of Air Force weather products such as the JET and the Air Force Weather Web Service (AFW-WEBS) through reachback communications to supplement forward applications such as the Integrated Weather Effects Decision Aid (IWEDA) and Weather Running Estimate (WRE). DCGS-A employs Ozone Widget technology and the DCGS Integrated Backbone (DIB) to distribute products to Mission Command and other users throughout the enterprise.

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.

The Corps of Engineers funds NOAA/National Weather Service (NWS) to collect and maintain precipitation information from 876 meteorological sites. The COE funds the NWS for hydro-meteorological studies and funds the U.S. Geological Survey (USGS) for maintaining hydro-meteorological data collection services for 2479 sites. The rest of the sites are maintained by the COE. U.S. Army Europe and U.S. Army Pacific maintain a small budget to fund Army owned automated weather sensing systems within their respective area of responsibility.

Elsewhere in the Army, budgets for meteorological operations and research do not change significantly from FY 2012 to FY 2013. Within the Army Materiel Command, the Army Research Laboratory (ARL) continued its research and development efforts in basic and applied atmospheric science. After undergoing a modest reduction in funding from FY 2010 to FY 2011, ARL anticipates no change in funding from FY 2012 to FY 2013. The Army Test and Evaluation Command's meteorology program budget will increase slightly from FY 2012 to FY 2013, with most of the increase going to instrumentation at the test ranges. The consolidation of the individual Four-Dimensional Weather (4DWX) computer systems in 2011-12 at each range to a primary system at Dugway Proving Ground (DPG) and a backup elsewhere, has gone smoothly, reducing acquisition costs and streamlining maintenance.

## DEPARTMENT OF HOMELAND SECURITY

### U.S. Coast Guard

All of the U.S. Coast Guard's (USCG) funding for meteorological programs is for operations support. For FY 2013, the requested funding level is $29.4 million. The Coast Guard does not have a specific program and budget for meteorology—all meteorological activities are accomplished as part of general operations. The Coast Guard's activities include the collection and dissemination of meteorological and iceberg warning information for the benefit of the marine community. The Coast Guard also collects coastal and marine observations from its shore stations and cutters and transmits these observations daily to the Navy's Fleet Numerical Meteorology and Oceanography Center and NOAA's National Weather Service. These observations are used by both the Navy and NOAA in generating weather forecasts.

The Coast Guard also disseminates a variety of weather forecast products and warnings to the marine community via radio transmissions. Coast Guard shore stations often serve as sites for NWS automated coastal weather stations, and the National Data Buoy Center provides logistics support in deploying and maintaining NOAA offshore weather buoys 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

### 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 $1.45 million on such efforts in FY 2013. 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; $140,000 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 2013 is $3.11 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-Department of Interior (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

The National Park Service (NPS) expends about $1.2 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 $1.8 million in routine air quality, visibility, and meteorological monitoring networks.

### U.S. Geological Survey

The U.S. Geological Survey expends approximately $66,000 per year conducting post-wildfire debris flow warning operations.

## DEPARTMENT OF TRANSPORTATION

### Federal Aviation Administration

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

For FY 2013, the FAA is requesting a total of $271 million for Aviation Weather related Systems Development, Operations Support, and Recurring Research and Development costs; an approximate 3% increase from FY 2012 actual funding received. The actual funding for the Aviation Weather Programs in 2012 was $264 million.

The changes are comprised of:

- An increase in reported numbers for Systems Development from an actually received $37 million in FY 2012 to a requested $51 million in FY 2013

- A decrease in reported numbers for Operations Support from an actually received $203 million in FY 2012 to a requested $200 million in FY 2013

- A decrease in reported numbers for Recurring R&D Costs from an actually received $22 million in FY 2012 to a requested $19 million in FY 2013

The funding changes reflect major initiatives in the Aviation Weather programs to support the Next Generation (NextGen) National Air Transportation System. These changes will bring increased and enhanced automation to the collection of Weather Observations, including the dissemination of weather products, graphics, and decision-making information; tools available for improved service by the air traffic facilities, pilots, the aviation industry, and general aviation users.

### Federal Highway Administration

Due to the extended time for road construction projects, the Department of Transportation does not go through an annual budget process but typically uses a six-year authorization. The latest transportation authorization for the Road Weather Management Program (RWMP) began in 2006 and has been extended through FY 2012 with level funding authorized at $5M each year over the life of the highway bill ─ the [SAFETEA-LU]. $4.6M was appropriated for FY2012. There is much uncertainty surrounding FY 2013 except that the funding levels will be less than over the period covered by the previous highway bill. Federal Highway Administration (FHWA) hopes to receive $2.0M for the

FY2013 budget. All of FHWA's funding is for applied research. The majority of 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.

## ENVIRONMENTAL PROTECTION AGENCY

All of the Environmental Protection Agency's (EPA) funding of meteorological and air quality programs is for supporting basic and applied research. The anticipated funding level in FY 2013 for directed meteorological research is about $7.2 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 2013 as in FY 2012.

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 2013 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $7.2 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 forecasts. 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 National Aeronautics and Space Administration's (NASA) estimated meteorological operations and research budget request for FY 2013 is $904,175,000. This request is an increase of 4.9 percent from the FY 2012 budget of $861,549,000.[1] The budget figures reported are based on relevant missions and programs in the Earth Science Division[2] and the Heliophysics Division[3] within the

[1] The budget request in FY 2011 was $877,894,000, which corrects the reporting error made in last year's report.

[2] The Earth Science Division reported budget includes an estimate of activities relevant to weather research and closely related program activities in observing research and data analysis. Research and satellite mission budgets are estimated

Science Mission Directorate, and the Human Exploration and Operations Mission Directorate. Across the directorates, NASA estimates the extent to which each mission and program contributes and relates to meteorological operations and research activities.

NASA Earth Science advances understanding of the Earth system, its components and their interactions, its changes, and the consequences of these changes for life. The program pioneers the use of remote sensing data, primarily space-based, in new and innovative ways, and leverages NASA's unique capabilities in global Earth observation. Earth Science Research sponsors basic disciplinary and interdisciplinary research, Earth system modeling efforts, the Airborne Science project (which provides access to aircraft and unmanned aircraft systems), and supercomputing efforts supporting a variety of programs, as well as education and outreach. At least 90 percent of the funds of the program are competitively awarded to investigators from academia, the private sector, and NASA Centers. The program uses satellite and airborne measurements, coupled with cutting-edge analyses and numerical models, to turn observations into information and understanding.

NASA takes an organized approach to address complex, interdisciplinary Earth science problems, integrating science across the programmatic elements in pursuit of a comprehensive understanding of the Earth system. The resulting programmatic structure comprises six interdisciplinary and interrelated science focus areas. These areas are:

- Climate Variability and Change: understanding the roles of ocean, atmosphere, land, and ice in the climate system and improving predictive capability for future evolution;
- Atmospheric Composition: understanding and improving predictive capability for changes in the ozone layer, climate forcing, and air quality associated with changes in atmospheric composition;
- Carbon Cycle and Ecosystems: quantifying, understanding and predicting changes in Earth's ecosystems and biogeochemical cycles, including the global carbon cycle, land cover, and biodiversity;
- Water and Energy Cycle: quantifying the key reservoirs and fluxes in the global water cycle and assessing water cycle change and water quality;
- Weather: enabling improved predictive capability for weather and extreme weather events; and
- Earth Surface and Interior: characterizing the dynamics of the Earth surface and interior and forming the scientific basis for the assessment and mitigation of natural hazards and response to rare and extreme events.

NASA also supports weather research through the Heliophysics Division and weather operations within the Human Exploration and Operations Mission Directorate (HEOMD). The objective of the

proportionally to their overall contributions to activities reported, noting that the majority of ESD's program aims to advance Earth System science.

[3] This report includes all resources that contribute to the advancement of space weather knowledge and to the transfer of that knowledge into operational space weather prediction systems. Space weather is a relatively immature field so that most NASA Heliophysics Division research assets and programs contribute significantly to the advancement of space weather prediction systems. NASA is currently the nation's major contributor to new knowledge in the area of space weather.

Heliophysics Division of NASA's Science Mission Directorate (SMD) is 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 interplanetary space. Research areas for the coming year include:

- New understanding of the ways that space storms are fueled by oxygen originating from Earth's own atmosphere.
- The surprising discovery that conditions in the Earth's ionosphere, thermosphere, and mesosphere are affected strongly by the terrestrial weather and climate below.
- The emergence of a long-term decline in the density of Earth's upper atmosphere, and how this change affects may affect weather systems below and space weather system above.

The HEOMD 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.

## NUCLEAR REGULATORY COMMISSION (NRC)

For FY 2013, the Nuclear Regulatory Commission's (NRC) total planned contract expenditures of $691,000 ($124,000 for operations and $567,000 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 (including rare external events such as extreme storms) that may impact safe operation of the facility, and the assessment of design or operational changes proposed for the facility.

Current and projected research activities include updating the hydrometeorological reports (HMR) and methods used to estimate the effects of extreme precipitation events, and developing an integrated approach for probabilistic flood hazard assessment (PFHA). During FY 2012, research was initiated to address 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 FY13 | Supporting Research | | | % of FY13 | Total | | | % of FY12 | % of FY13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGENCY | FY12 | FY13 | %CHG | TOTAL | FY12 | FY13 | %CHG | TOTAL | FY12 | FY13 | %CHG | TOTAL | TOTAL |
| Agriculture | 18899 | 19021 | 0.6 | 0.5 | 46013 | 43113 | -6.3 | 3.4 | 64912 | 62134 | -4.3 | 1.4 | 1.3 |
| Commerce/NOAA(Subtot) | 2879118 | 3025271 | 5.1 | 86.7 | 169101 | 170447 | 0.8 | 13.6 | 3048219 | 3195718 | 4.8 | 67.2 | 67.4 |
| NWS | 973476 | 954756 | -1.9 | 27.4 | 22539 | 21637 | -4.0 | 1.7 | 996015 | 976393 | -2.0 | 22.0 | 20.6 |
| NESDIS | 1851178 | 2013219 | 8.8 | 57.7 | 26667 | 26987 | 1.2 | 2.2 | 1877845 | 2040206 | 8.6 | 41.4 | 43.0 |
| OAR | 0 | 0 | 0 | 0 | 118395 | 120323 | 1.6 | 9.6 | 118395 | 120323 | 1.6 | 2.6 | 2.5 |
| NOS | 27530 | 29055 | 5.5 | 0.8 | 0 | 0 | 0 | 0 | 27530 | 29055 | 5.5 | 0.6 | 0.6 |
| OMAO | 26934 | 28241 | 4.9 | 0.8 | 1500 | 1500 | 0.0 | 0.1 | 28434 | 29741 | 4.6 | 0.6 | 0.6 |
| Defense(Subtot) | 193012 | 206029 | 6.7 | 5.9 | 54052 | 52816 | -2.3 | 4.2 | 247064 | 258845 | 4.8 | 5.4 | 5.5 |
| Air Force | 105370 | 107493 | 2.0 | 3.1 | 30919 | 29048 | -6.1 | 2.3 | 136289 | 136541 | 0.2 | 3.0 | 2.9 |
| Navy | 69765 | 74648 | 7.0 | 2.1 | 9500 | 9880 | 4.0 | 0.8 | 79265 | 84528 | 6.6 | 1.7 | 1.8 |
| Army | 17877 | 23888 | 33.6 | 0.7 | 13633 | 13888 | 1.9 | 1.1 | 31510 | 37776 | 19.9 | 0.7 | 0.8 |
| Homeland Security (Subtot) | 28500 | 29410 | 3.2 | 0.8 | 0 | 0 | 0 | 0 | 28500 | 29410 | 3.2 | 0.6 | 0.6 |
| USCG | 28500 | 29410 | 3.2 | 0.8 | 0 | 0 | 0 | 0 | 28500 | 29410 | 3.2 | 0.6 | 0.6 |
| Interior/BLM (Subtot) | 6795 | 6829 | 0.5 | 0.2 | 1700 | 1200 | -29.4 | 0.1 | 8495 | 8029 | -5.5 | 0.2 | 0.2 |
| BLM | 4729 | 4963 | 4.9 | 0.1 | 0 | 0 | 0 | 0 | 4729 | 4963 | 4.9 | 0.1 | 0.1 |
| NPS | 2000 | 1800 | -10.0 | 0.1 | 1700 | 1200 | -29.4 | 0.1 | 3700 | 3000 | -18.9 | 0.1 | 0.1 |
| USGS | 66 | 66 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 66 | 66 | 0.0 | 0.0 | 0.0 |
| Transportation(Subtot) | 203903 | 200985 | -1.4 | 5.8 | 64974 | 72862 | 12.1 | 5.8 | 268877 | 273847 | 1.8 | 5.9 | 5.8 |
| FAA | 203903 | 200985 | -1.4 | 5.8 | 60374 | 70862 | 17.4 | 5.7 | 264277 | 271847 | 2.9 | 5.8 | 5.7 |
| FHWA | 0 | 0 | 0 | 0 | 4600 | 2000 | -56.5 | 0.2 | 4600 | 2000 | -56.5 | 0.1 | 0.0 |
| EPA | 0 | 0 | 0 | 0 | 8000 | 7200 | -10.0 | 0.6 | 8000 | 7200 | -10.0 | 0.2 | 0.2 |
| NASA | 7898 | 1603 | -79.7 | 0.0 | 853651 | 902572 | 5.7 | 72.2 | 861549 | 904175 | 4.9 | 19.0 | 19.1 |
| NRC | 32 | 124 | 287.5 | 0.0 | 340 | 567 | 66.8 | 0.0 | 372 | 691 | 85.8 | 0.0 | 0.0 |
| DOE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 3338157 | 3489272 | 4.5 | 100.0 | 1197831 | 1250777 | 4.4 | 100.0 | 4535988 | 4740049 | 4.5 | 100.0 | 100.0 |
| % of FY TOTAL | 73.6% | 73.6% | | | 26.4% | 26.4% | | | 100.0% | 100.0% | | | |

*The FY 2012 funding reflects Congressionally appropriated funds; the FY 2013 funding reflects the amount requested in the President's FY 2013 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 "Major Systems Acquisition." To a large degree, these categories correspond to non-hardware costs (Operations Support) and hardware costs (Systems Acquisition).

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

| | Operations Support | | Major Systems Acquisition | | Total | | | % of FY13 |
|---|---|---|---|---|---|---|---|---|
| AGENCY | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | %CHG | TOTAL |
| Agriculture | 18899 | 19021 | 0 | 0 | 18899 | 19021 | 0.6 | 0.5 |
| Commerce/NOAA(Subtot) | 1102268 | 1103637 | 1776850 | 1921634 | 2879118 | 3025271 | 5.1 | 86.7 |
| NWS | 893271 | 883431 | 80205 | 71325 | 973476 | 954756 | -1.9 | 27.4 |
| NESDIS | 154533 | 162910 | 1696645 | 1850309 | 1851178 | 2013219 | 8.8 | 57.7 |
| OAR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NOS | 27530 | 29055 | 0 | 0 | 27530 | 29055 | 5.5 | 0.8 |
| OMAO | 26934 | 28241 | 0 | 0 | 26934 | 28241 | 4.9 | 0.8 |
| Defense(Subtot) | 161231 | 166298 | 31781 | 39731 | 193012 | 206029 | 6.7 | 5.9 |
| Air Force | 81149 | 82727 | 24221 | 24766 | 105370 | 107493 | 2.0 | 3.1 |
| Navy | 68300 | 73081 | 1465 | 1567 | 69765 | 74648 | 7.0 | 2.1 |
| Army | 11782 | 10490 | 6095 | 13398 | 17877 | 23888 | 33.6 | 0.7 |
| Homeland Security (Subtot) | 28500 | 29410 | 0 | 0 | 28500 | 29410 | 3.2 | 0.8 |
| USCG | 28500 | 29410 | 0 | 0 | 28500 | 29410 | 3.2 | 0.8 |
| Interior/BLM | 6795 | 6829 | 0 | 0 | 6795 | 6829 | 0.5 | 0.2 |
| BLM (Subtot) | 4729 | 4963 | 0 | 0 | 4729 | 4963 | 4.9 | 0.1 |
| SWA | 1360 | 1450 | 0 | 0 | 1360 | 1450 | 6.6 | 0.0 |
| OFA | 3369 | 3513 | 0 | 0 | 3369 | 3513 | 4.3 | 0.1 |
| NPS | 2000 | 1800 | 0 | 0 | 2000 | 1800 | -10.0 | 0.1 |
| USGS | 66 | 66 | 0 | 0 | 66 | 66 | 0.0 | 0.0 |
| Transportation(Subtot) | 203903 | 200985 | 0 | 0 | 203903 | 200985 | -1.4 | 5.8 |
| FAA | 203903 | 200985 | 0 | 0 | 203903 | 200985 | -1.4 | 5.8 |
| FHWA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EPA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NASA | 1708 | 1603 | 6190 | 0 | 7898 | 1603 | -79.7 | 0.0 |
| NRC | 32 | 124 | 0 | 0 | 32 | 124 | 287.5 | 0.0 |
| DOE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 1523336 | 1527907 | 1814821 | 1961365 | 3338157 | 3489272 | 4.5 | 100.0 |
| % of FY TOTAL | 45.6% | 43.8% | 54.4% | 56.2% | 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, broken down by budget categories. The agencies' supporting research budgets are subdivided along similar lines of operational funding--Research and Development (non-hardware) and Systems Development (hardware). For FY 2013, agencies will obligate a total of $1.25 billion in supporting research funds in the following manner: $615 million to research and development, $635 million to systems development.

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

| AGENCY | Recurring R&D Costs FY12 | Recurring R&D Costs FY13 | Systems Development FY12 | Systems Development FY13 | Total FY12 | Total FY13 | Total %CHG | % of FY13 TOTAL |
|---|---|---|---|---|---|---|---|---|
| Agriculture | 45031 | 42131 | 982 | 982 | 46013 | 43113 | -6.3 | 3.4 |
| Commerce/NOAA(Subtot) | 157894 | 157513 | 11207 | 12934 | 169101 | 170447 | 0.8 | 13.6 |
| NWS | 13702 | 11073 | 8837 | 10564 | 22539 | 21637 | -4.0 | 1.7 |
| NESDIS | 26667 | 26987 | 0 | 0 | 26667 | 26987 | 1.2 | 2.2 |
| OAR | 116525 | 118453 | 1870 | 1870 | 118395 | 120323 | 1.6 | 9.6 |
| NOS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OMAO-AOC | 1000 | 1000 | 500 | 500 | 1500 | 1500 | 0.0 | 0.1 |
| Defense(Subtot) | 35239 | 40618 | 18813 | 12198 | 54052 | 52816 | -2.3 | 4.2 |
| Air Force | 12106 | 16850 | 18813 | 12198 | 30919 | 29048 | -6.1 | 2.3 |
| Navy | 9500 | 9880 | 0 | 0 | 9500 | 9880 | 4.0 | 0.8 |
| Army | 13633 | 13888 | 0 | 0 | 13633 | 13888 | 1.9 | 1.1 |
| Homeland Security (Subtot) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| USCG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Interior/BLM | 1700 | 1200 | 0 | 0 | 1700 | 1200 | -29.4 | 0.1 |
| BLM (Subtot) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SWA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OFA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NPS | 1700 | 1200 | 0 | 0 | 1700 | 1200 | -29.4 | 0.1 |
| USGS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Transportation(Subtot) | 27574 | 21262 | 37400 | 51600 | 64974 | 72862 | 12.1 | 5.8 |
| FAA | 22974 | 19262 | 37400 | 51600 | 60374 | 70862 | 17.4 | 5.7 |
| FHWA | 4600 | 2000 | 0 | 0 | 4600 | 2000 | -56.5 | 0.2 |
| EPA | 8000 | 7200 | 0 | 0 | 8000 | 7200 | -10.0 | 0.6 |
| NASA | 324780 | 344505 | 528871 | 558067 | 853651 | 902572 | 5.7 | 72.2 |
| NRC | 340 | 567 | 0 | 0 | 340 | 567 | 66.8 | 0.0 |
| DOE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 600558 | 614996 | 597273 | 635781 | 1197831 | 1250777 | 4.4 | 100.0 |
| % of FY TOTAL | 50.1% | 49.2% | 49.9% | 50.8% | 100.0% | 100.0% | | |

## Tables 4 and 5, Operational Costs and Supporting Research Costs by Service Category

Tables 4 and 5 reflect how the agencies plan to obligate FY 2013 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.
- ***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.
- ***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.

- ***Climate Services.*** Climate services are specialized meteorological and hydrological services established to meet the requirements of Federal, state, and local agencies for information on the historical, current, and future state of the earth system. Climate services include observations, monitoring, assessments, predictions, and projections of the atmosphere, hydrosphere, and land surface systems.
- ***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.
- ***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).
- ***Space Weather Services.*** Space weather services are those specialized meteorological services and facilities established to meet the needs of users for information on space weather conditions and space weather storms that can affect terrestrial systems, the Earth's atmosphere, and the near-Earth space environment. Space weather services include monitoring and reporting of space weather storms and their effects on the Earth's atmosphere, ionosphere, and geomagnetic fields. Early warning of an approaching space weather storm, so that timely protective response is possible, is an important part of space weather services.
- ***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.
- ***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.
- ***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 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 |
| Agriculture | 0 | 0 | 1134 | 1205 | 0 | 0 | 0 | 0 | 0 | 0 | 9300 | 9300 | 0 | 0 | 0 | 0 | 0 | 0 | 8465 | 8516 | 0 | 0 | 18899 | 19021 |
| Commerce/NOAA(Subtot) | 2708170 | 2833545 | 0 | 0 | 62740 | 77226 | 13691 | 16158 | 0 | 0 | 53628 | 53750 | 0 | 0 | 10099 | 10835 | 27530 | 29055 | 1610 | 1552 | 1650 | 3150 | 2879118 | 3025271 |
| NWS | 830608 | 792685 | 0 | 0 | 62740 | 77226 | 13691 | 16158 | 0 | 0 | 53078 | 53150 | 0 | 0 | 10099 | 10835 | 0 | 0 | 1610 | 1552 | 1650 | 3150 | 973476 | 954756 |
| NESDIS | 1851178 | 2013219 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1851178 | 2013219 |
| 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 | 27530 | 29055 | 0 | 0 | 0 | 0 | 27530 | 29055 |
| OMAO | 26384 | 27641 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 550 | 600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26934 | 28241 |
| Defense(Subtot) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 182527 | 198379 | 10485 | 7650 | 0 | 0 | 0 | 0 | 0 | 0 | 193012 | 206029 |
| Air Force | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 94885 | 99843 | 10485 | 7650 | 0 | 0 | 0 | 0 | 0 | 0 | 105370 | 107493 |
| Navy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 69765 | 74648 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 69765 | 74648 |
| Army | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17877 | 23888 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17877 | 23888 |
| Homeland Security (Subtot) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28500 | 29410 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28500 | 29410 |
| USCG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28500 | 29410 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28500 | 29410 |
| Interior/BLM | 0 | 0 | 1360 | 1450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3435 | 3579 | 2000 | 1800 | 6795 | 6829 |
| BLM (Subtot) | 0 | 0 | 1360 | 1450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3369 | 3513 | 0 | 0 | 4729 | 4963 |
| SWA | 0 | 0 | 1360 | 1450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1360 | 1450 |
| 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 | 1800 | 2000 | 1800 |
| USGS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 66 | 66 | 0 | 0 | 66 | 66 |
| Transportation(Subtot) | 0 | 0 | 0 | 0 | 203903 | 200985 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 203903 | 200985 |
| FAA | 0 | 0 | 0 | 0 | 203903 | 200985 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 203903 | 200985 |
| 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 | 1000 | 1000 | 0 | 0 | 0 | 0 | 6898 | 603 | 7898 | 1603 |
| NRC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 124 | 32 | 124 |
| 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 | 2708170 | 2833545 | 2494 | 2655 | 266643 | 278211 | 13691 | 16158 | 28500 | 29410 | 62960 | 63050 | 182527 | 198379 | 21584 | 19485 | 27530 | 29055 | 13510 | 13647 | 10548 | 5677 | 3338157 | 3489272 |
| % of FY TOTAL | 81.1% | 81.2% | 0.1% | 0.1% | 8.0% | 8.0% | 0.4% | 0.5% | 0.9% | 0.8% | 1.9% | 1.8% | 5.5% | 5.7% | 0.6% | 0.6% | 0.8% | 0.8% | 0.4% | 0.4% | 0.3% | 0.2% | 100.0% | 100.0% |

## TABLE 5 Supporting Research and Development 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 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 | FY12 | FY13 |
| Agriculture | 0 | 0 | 14918 | 14531 | 0 | 0 | 22264 | 19751 | 0 | 0 | 947 | 947 | 0 | 0 | 0 | 0 | 0 | 0 | 7884 | 7884 | 0 | 0 | 46013 | 43113 |
| Commerce/NOAA(Subtot) | 94659 | 97754 | 0 | 0 | 8069 | 4298 | 50971 | 51853 | 1074 | 1098 | 13878 | 14244 | 0 | 0 | 0 | 750 | 0 | 0 | 0 | 0 | 450 | 450 | 169101 | 170447 |
| NWS | 16095 | 18214 | 0 | 0 | 6444 | 2673 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 0 | 0 | 0 | 0 | 0 | 0 | 22539 | 21637 |
| NESDIS | 26,667 | 26,987 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26667 | 26987 |
| OAR | 50897 | 51553 | 0 | 0 | 1625 | 1625 | 50971 | 51853 | 1074 | 1098 | 13828 | 14194 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 118395 | 120323 |
| 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-AOC | 1000 | 1000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 450 | 450 | 1500 | 1500 |
| Defense(Subtot) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48675 | 47963 | 5377 | 4853 | 0 | 0 | 0 | 0 | 0 | 0 | 54052 | 52816 |
| Air Force | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25542 | 24195 | 5377 | 4853 | 0 | 0 | 0 | 0 | 0 | 0 | 30919 | 29048 |
| Navy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9500 | 9880 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9500 | 9880 |
| Army | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13633 | 13888 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13633 | 13888 |
| 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 | 1200 | 1700 | 1200 |
| 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 | 1700 | 1200 | 1700 | 1200 |
| USGS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Transportation(Subtot) | 0 | 0 | 0 | 0 | 60374 | 70862 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4600 | 2000 | 0 | 0 | 0 | 0 | 64974 | 72862 |
| FAA | 0 | 0 | 0 | 0 | 60374 | 70862 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60374 | 70862 |
| FHWA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4600 | 2000 | 0 | 0 | 0 | 0 | 4600 | 2000 |
| EPA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8000 | 7200 | 8000 | 7200 |
| NASA | 0 | 0 | 0 | 0 | 0 | 0 | 250941 | 266529 | 0 | 0 | 0 | 0 | 0 | 0 | 601356 | 634645 | 0 | 0 | 0 | 0 | 1354 | 1398 | 853651 | 902572 |
| NRC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 20 | 300 | 520 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 340 | 567 |
| 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 | 94659 | 97754 | 14918 | 14531 | 68443 | 75160 | 324176 | 338133 | 1114 | 1118 | 15125 | 15711 | 48675 | 47963 | 606733 | 640248 | 4600 | 2000 | 7884 | 7884 | 11504 | 10275 | 1197831 | 1250777 |
| % of FY TOTAL | 7.9% | 7.8% | 1.2% | 1.2% | 5.7% | 6.0% | 27.1% | 27.0% | 0.1% | 0.1% | 1.3% | 1.3% | 4.1% | 3.8% | 50.7% | 51.2% | 0.4% | 0.2% | 0.7% | 0.6% | 1.0% | 0.8% | 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 2013 is 12,142, an 11.3% decrease from FY 2012.

**TABLE 6 Personnel Engaged in Meteorlological Operations**

(Units are Full time Equivalent Staff Years)*

| AGENCY | FY 2012 | FY 2013 | %CHG | % of FY 13 TOTAL | |
|---|---|---|---|---|---|
| Agriculture | 130 | 130 | 0.0 | 1.1 | |
| Commerce/NOAA (sub-total) | 5920 | 6047 | 2.1 | 49.8 | |
| NWS | 4679 | 4544 | -2.9 | 37.4 | |
| NESDIS (sub-total) | 558 | 818 | 46.6 | 6.7 | |
| NESDIS | 558 | 818 | 46.6 | 6.7 | |
| Reimbursed | 0 | 0 | 0 | 0 | |
| OAR | 459 | 459 | 0.0 | 3.8 | |
| NOS | 120 | 122 | 1.7 | 1.0 | |
| OMAO-AOC | 104 | 104 | 0.0 | 0.9 | |
| Defense(Subtotal) | 6342 | 4665 | -26.4 | 38.4 | |
| Air Force | 5480 | 3802 | -30.6 | 31.3 | *FY13 does not include Guard and Reserve |
| Navy | 415 | 415 | 0.0 | 3.4 | |
| Marine Corps | 370 | 370 | 0.0 | 3.0 | |
| Army | 77 | 78 | 1.3 | 0.6 | |
| Homeland Security-USCG | 108 | 108 | 0.0 | 0.9 | |
| Interior/BLM(Subtotal) | 45 | 44 | -2.2 | 0.4 | |
| BLM Soil/Water/Air Program | 10 | 10 | 0.0 | 0.1 | |
| BLM Fire Weather Program | 35 | 34 | -2.9 | 0.3 | |
| Transportation(Subtotal) | 1140 | 1140 | 0.0 | 9.4 | |
| FHWA | 0 | 0 | 0 | 0 | |
| FAA | 1140 | 1140 | 0.0 | 9.4 | |
| EPA | 0 | 0 | 0 | 0 | |
| NASA | 3 | 3 | 0.0 | 0.0 | |
| NRC | 5 | 5 | 0.0 | 0.0 | |
| DOE | 0 | 0 | 0 | 0 | |
| TOTAL | 13693 | 12142 | -11.3 | 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

This table summarizes the reimbursement of funds from one agency to another during FY 2012. Agencies routinely enter into reimbursable agreements when they determine that one agency can provide the activity more effectively than the other. While specific amounts may vary from year-to-year, the pattern shown is essentially stable and reflects a significant level of interagency cooperation.

**TABLE 7 Interagency Fund Transfers**
**for Meteorological Operations and Supporting Research**

| | | FY12 Funds ($K) | | | |
|---|---|---|---|---|---|
| | | Estimated or Planned | | | |
| Agency Funds | Agency Funds | | Supporting | | |
| Transferred from: | Transferred to: | Operations | Research | | |
| USDA/USFS | DOI/BLM | 831 | | | |
| NESDIS | | 0 | 0 | | |
| Air Force Weather | DOC/NOAA/NWS | 1,539 | | | |
| Air Force Weather | DOC/NOAA/NESDIS | 88 | | | |
| Air Force Weather | DOC/NOAA/OAR | | 275 | | |
| Air Force Weather | DOC/OFCM | 156 | | | |
| Air Force Weather | USGS (Dept of Interior) | 546 | | | |
| Air Force Weather | NASA | 381 | 1346 | | |
| Air Force Weather | NSF | 600 | | | |
| Air Force Weather | NSF/UCAR/NCAR | | 2596 | | |
| Corps of Engineers | National Weather Service | 260 | 215 | | |
| Corps of Engineers | US Geological Survey | 18922 | 0 | | |
| Army | OFCM | 65 | 0 | | |
| | | | | | |
| | | | | | |
| FAA(Contract Weather) | NWS APAIDS in Alaska | 128 | | | |
| FAA(Contract Weather) | NWS Cascade Locks | 13 | | | |
| FAA(Contract Weather) | NWS Meteorologists | 388 | | | |
| FAA(NEXRAD) | NWS | 2500 | | | |
| FAA(ASOS) | NWS | 12479 | | | |
| NASA | DOD/USAF/45th Space Wing | 800 | 0 | | |
| | DOD/USAF/Edwards AFB | 0 | 0 | | |
| | DOC/NOAA/NDBC | 132 | 0 | | |
| | DOC/NOAA/SMG | 400 | 0 | | |
| 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 2012 Locations |
|---|---|---|
| **Surface, land** | | |
| Commerce (NWS all types) | | 841 |
| Commerce (OAR manned Atmospheric Baseline Observations) | | 6 |
| Commerce (OAR Climate Reference Network) | | 122 |
| Air Force (U.S. & Overseas) | | 175 |
| Navy (U.S. & Overseas) | | 68 |
| Marine Corps (U.S. & Overseas) | | 24 |
| Army (U.S. & Overseas) | | 55 |
| 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 (FAA Flight Service Stations in Alaska)*** | | 17 |
| Transportation (FHWA-Road Wx Obsg Stn) | | 2435 |
| Homeland Security (USCG Coastal) | | 50 |
| Interior (BLM Soil/Water/Air Program) | | 200 |
| Interior (BLM Office of Fire and Aviation) | | 971 |
| Agriculture | | 1043 |
| Agriculture (NRCS active manual snow courses) | | 995 |
| Agriculture (NRCS automated SNOTEL stations) | | 834 |
| Agriculture (NRCS automated SCAN stations) | | 183 |
| NASA (all types) | | 0 |
| | Total | 8961 |

*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 1400)
***Note: 17 Flight Service Stations in Alaska since 2007 owned and supported by Harris Corporation

| | | |
|---|---|---|
| **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) | | 182 |
| Navy (Ships with met personnel) | | 29 |
| Navy (Ships without met personnel) | | 253 |
| Homeland Security (USCG Cutters) | | 250 |
| NASA (Buoys - moored) | | 0 |
| | Total | 1577 |

**TABLE 8 Facilities/Locations Taking Meteorological Observations, Continued**

| | | |
|---|---|---|
| **Upper air, balloon** | | |
| Commerce (U.S.) | | 102 |
| Commerce (Foreign, Cooperative) | | 22 |
| Commerce (met/ozone/water vapor) | | 17 |
| Air Force, Mobile | | 29 |
| Army, Fixed (U.S. & Overseas) | | 9 |
| Army, Mobile (U.S. and Overseas) | | 5 |
| Navy, Fixed (U.S. & Overseas) | | 0 |
| Navy, Mobile(U.S. & Overseas) | | 10 |
| Navy, Ships | | 29 |
| Marine Corps, Mobile | | 8 |
| NASA (U.S. and Overseas) | | 13 |
| | Total | 244 |
| **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 | | 4 |
| NASA (50 MHz) | | 1 |
| | Total | 23 |
| **Doppler weather radar (WSR-88D) sites** | | |
| Commerce (NWS) | | 122 |
| Air Force (U.S. & Overseas) | | 26 |
| Transportation-FAA (Off CONUS) | | 12 |
| | Sub-total | 160 |
| **Doppler weather radar (Not WSR-88D) sites** | | |
| Air Force (Fixed) | | 15 |
| Army | | 3 |
| Navy (Fixed) | | 9 |
| Commerce (Research Phased Array Radar- NWRT) | | 1 |
| | Sub-total | 27 |
| **Airport Terminal Doppler weather radars** | | |
| Transportation-FAA (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 |
| | | 303 |

**TABLE 8 Facilities/Locations Taking Meteorological Observations, Continued**

| | | | |
|---|---|---|---|
| Air Force (OPUPs only) | | | 99 |
| Marine Corps (U.S. & Overseas) | | | 9 |
| Army | | | 1 |
| | Total | | 109 |
| **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 |
| NESDIS | **Total** | | **4** |
| GOES 12 - South America | | 1 | |
| GOES 13 - Operational East | | 1 | |
| GOES 14 - On-Orbit Storage | | 1 | |
| GOES 15 - Operational West | | 1 | |
| http://www.oso.noaa.gov/goesstatus/ | | | |
| **Polar meteorological satellites (No. operating)** | | | |
| Commerce (1 PM primary, 1 European AM Primary, 3 Secondaries, 1 Backup) | | | 6 |
| NESDIS | **Total** | | **6** |
| METOP-A - AM Primary | | 1 | |
| NOAA 15 - AM Secondary | | 1 | |
| NOAA 16 - PM Secondary | | 1 | |
| NOAA 17 - AM Backup | | 1 | |
| NOAA 18 - PM Secondary | | 1 | |
| NOAA 19 - PM Primary | | 1 | |
| http://www.oso.noaa.gov/poesstatus/ | | | |
| Air Force (2 primary, 2 secondary, 2 tactical) | | | 6 |
| Navy (WINDSAT and GFO) | | | 1 |
| | Total | | 7 |
| **Electric Field Mills (Surface)** | | | |
| NASA (KSC) | | | 0 |
| Army | | | 5 |
| | Total | | 0 |
| **Lightning Detection Systems** | | | |
| Air Force (ER&WR - Cloud - Ground) | | | 2 |
| Air Force (ER&WR - NLDN) | | | 2 |
| Army | | | 7 |
| | Total | | 11 |
| **Rocketsondes** | | | |
| Army | Total | | 1 |

# 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.

The 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. The members who serve on these entities 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 the 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.

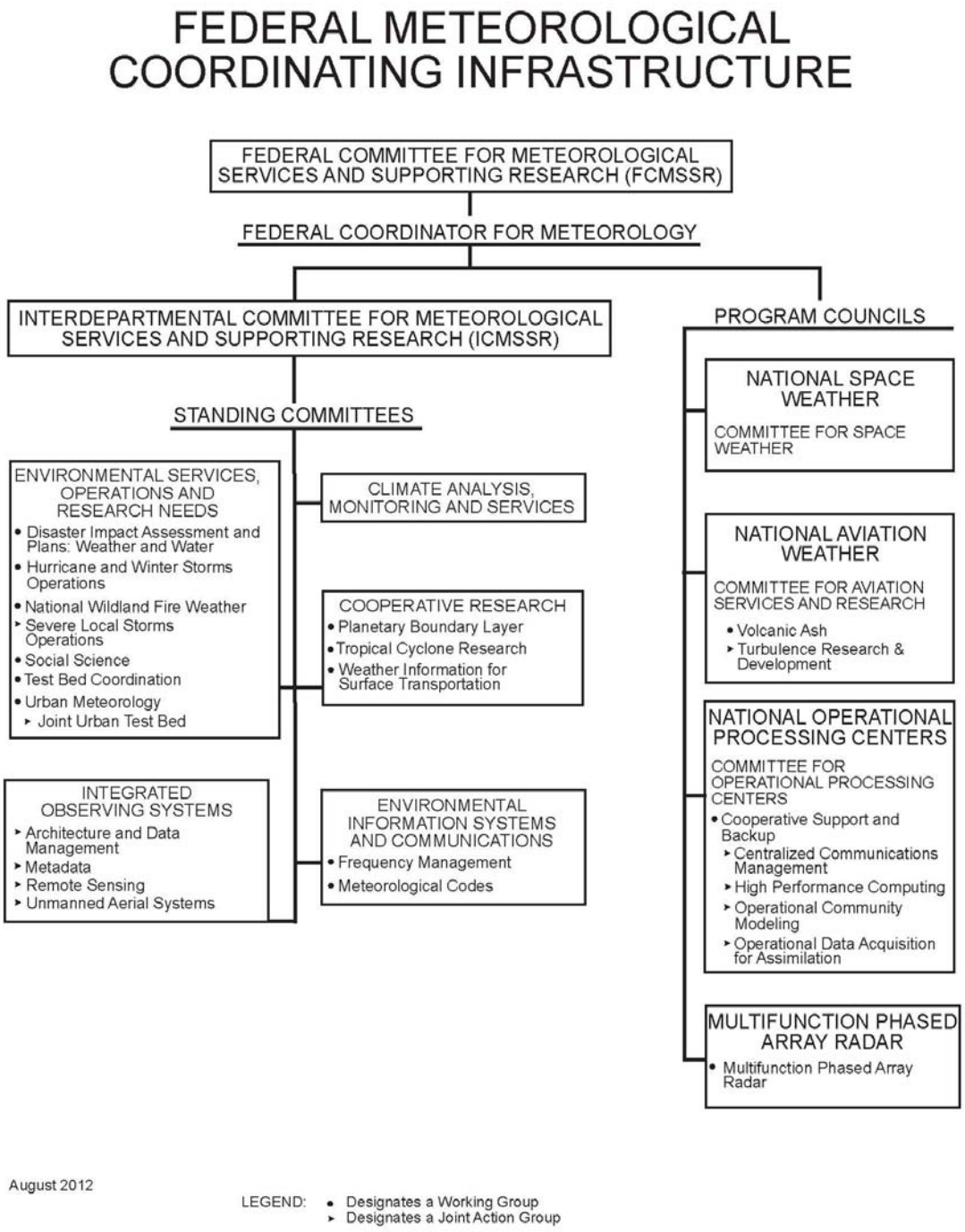
The FCMSSR comprises representatives of the 15 Federal agencies that engage in meteorological activities or supporting research, have a major need for meteorological services, or set policy and direction for such services and research. These 15 agencies are the Departments of Agriculture (USDA), Commerce (DOC), Defense (DOD), Energy (DOE), Homeland Security (DHS), the Interior (DOI), State (DOS), and Transportation (DOT); the Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), National Transportation Safety Board (NTSB), and Nuclear Regulatory Commission (NRC); 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

The OFCM Coordinating Infrastructure Diagram, on page 2-5, shows the current infrastructure of program councils, committees, working groups (WG), and joint action groups (JAG) through which the 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 diagram, 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 the 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.



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 2012 AND PLANS FOR FISCAL YEAR 2013

Federal coordination activities during FY 2012 and plans for FY 2013 are discussed here under the Program Council or ICMSSR standing committee that provided oversight of the associated working group or joint action group.

### Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act 2012

On June 29, 2012, Congress passed the Federal highway conference bill which was then signed into law by the President on 6 July. The bill included legislation to establish the Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act. The COASTAL Act is intended to lower costs to the National Flood Insurance Program (NFIP) by better discerning wind versus storm surge damages in the case of "clean slabs," where little tangible evidence beyond a building's foundation remains for the proper adjustment of insurance claims for homes totally destroyed by a hurricane or tropical storm. This will enable a more timely claims adjustment process which has frequently faced excessive delays due to litigation between the Federal government and private insurers, resulting from an inability to determine to what extent the damage should be covered by the NFIP or by private insurers covering wind damage.

Under the new law, NOAA is required to produce detailed post-storm analyses following named storms that impact the coastal zone of the U.S. These analyses are then required to be submitted to DHS/FEMA within 90 days. NOAA is required to make all data and post-storm assessments available to the public and to maintain an online database. The database and post-storm model are mandated to be operational by Dec. 28, 2013 (540 days after enactment).

As defined in the COASTAL Act language, NOAA, in consultation with the OFCM, is required to provide several interim deliverables to Congress, including an assessment of current capabilities and needs to provide the required post-storm analyses. The OFCM is working closely with the NOAA Legislative Liaison and members from the Line Offices to link NOAA's efforts with the interagency resources coordinated through the OFCM. The OFCM is leveraging

its interagency coordinating infrastructure, including the Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (WG/DIAP), for this effort. Additionally, the OFCM has reached out to other agencies not currently engaged on the WG/DIAP, including NSF and NASA and has developed a COASTAL Act Project Work Plan to guide the interagency effort.

On September 11, 2012, the WG/DIAP met to discuss the project work plan and agreed to establish the Joint Action Group for the COASTAL Act Post-Storm Analysis (JAG/CAPSA) to implement the plan. The new JAG will be co-chaired by the USGS, US Army Corps of Engineers, and a senior manager from NOAA-NWS. In all, about 30 people from a dozen organizations participated in the kick-off meeting.

### National Earth Observations Assessment

The OFCM has been an active and lead participant in several phases of the Office of Science and Technology Policy (OSTP)-sponsored National Earth Observations Assessment. This assessment is in response to Congressional direction to the OSTP Director to develop a national observing system portfolio organized around 13 Societal Benefit Areas (SBA). This observing system portfolio has two components: (1) a baseline assessment of current Earth observation systems, networks, and platforms and (2) a recommended portfolio (of required current, planned, and new capabilities) for the next 10 years. The assessment also identified data gaps, new technologies, and research to address current gaps and emerging observing needs. The OFCM led a team of NOAA subject matter experts in the assessment process for the weather SBA and supports the assessment working group. See the report under the National Space Weather Program Council for more on OFCM involvement in this initiative.

### National Aviation Weather Program Council

The OFCM supports implementation of the National Aviation Weather Program, which is a broad interagency effort to advance meteorological standards, improve products, enhance services, and conduct research that contributes to the overall goal of providing the best state-of-the-art information to aviation end users where and when they need it. The OFCM also participates in the Next Generation Air Transportation System (NextGen) Weather Working Group (NWWG) and the Friends/Partners in Aviation Weather (FPAW).

The Committee for Aviation Services and Research (CASR) made significant strides toward developing a NextGen Weather Research and Development Roadmap that will provide a plan for meeting 4D Weather Data Cube content requirements for the NextGen Mid-term Operational Capability (MOC) in 2018. Leveraging National Weather Service (NWS) work that was already underway, CASR surveyed the agencies to discover and catalog the aviation weather-related R&D that was underway or planned and then applied the various FAA requirements documents to formulate a plan for moving forward, involving a phased approach with science aspects being addressed first, followed by infrastructure considerations. To address the over 1500 individual requirements, CASR grouped them by “service areas” and is forming JAGs to address each area. JAGs were established sequentially to manage workload, with turbulence being addressed first. This work will continue into 2013. The CASR will consolidate the input from the JAGs into a comprehensive science plan, after which information from the JAGs will be used to address

infrastructure gaps. The CASR will also make a concerted effort, in cooperation with the NextGen Joint Planning and Development Office, to determine and catalog the aviation weather-related research being performed by industry.

The CASR tracked the work underway on the FAA Research Evolution Planning initiative, and the OFCM participated in that effort.

The National Aviation Weather Program Council met in 2012 to review CASR's work on the R&D plan and will continue to track that work going forward.

Aviation weather-related work by the OFCM on the Pilot Report (PIREP) code is included later in this section under the Committee for Environmental Information Systems and Communications.

### National Operational Processing Centers Program Council

During FY 2012, the OFCM continued to organize and lead the National Operations Processing Centers Program Council (NOPC). The NOPC is the umbrella organization for the Committee for Operational Processing Centers (COPC). As such, the NOPC facilitates improved collaboration among the NOPC organizations which have direct oversight of the COPC-member offices. The NOPC organizations include: the National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS), the NOAA/National Environmental Satellite, Data, and Information Service (NESDIS), the U.S. Navy (Navy Meteorology and Oceanography Command), and the U.S. Air Force (Directorate of Weather). The NOPC Principals set policy; provide strategic vision, planning, program guidance, and interagency funding authority; identify future roadmap capabilities for their own agencies; determine how to effectively position themselves for future requirements and collaboration; and identify coordinated approaches to solving the Nation's highest priority environmental information needs.

Meetings of the NOPC were held on January 18, 2012, and June 13, 2012. The meetings provided a platform for discussing and/or prioritizing (1) OPC resources, (2) new and existing requirements, (3) updates on satellites programs, (4) a Federally-sanctioned, inter-NOPC partnership, and (4) a communications network for meteorological and oceanographic data exchange. The meetings also facilitated knowledge of (and resulting interagency interest in) partnership proposals between research facilities and OPCs.

At these meetings, the NOPC Principals also recognized the value of basic research related to modeling and data assimilation. As a result, the OFCM utilized its coordinating infrastructure to advance NSF's efforts, along with NOPC-member organizations and other interested agencies, to define key focus areas to launch a program similar to NOAA's Hurricane Forecast Improvement Program to address national needs and priorities relative to NOPC organizations. Additionally, the OFCM continued coordinating NSF to expand (1) the NSF-NOAA Visiting Scientist (2) the university-based ensemble, and (3) the NSF Science, Engineering, and Education for Sustainability–Creating a More Disaster Resilient America programs to other NOPC-member organizations. At each NOPC meeting, NESDIS provided routine Joint Polar Satellite System Program updates. Other topics; such as, the Defense Meteorological Satellite Program Follow-

on and the Non-secure Internet Protocol Router Network (NIPRNet) Federated Gateway are included on the NOPC agenda as interest or events dictate.

### Committee for Operational Processing Centers

In FY 2012, 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. COPC hosted a successful Observational Data Workshop (ODW) in FY 2012, helping set the stage for a concentrated effort to improve the assimilation of data into our numerical weather prediction models. During the two-day workshop, representatives of the national operational processing centers and other national data centers discussed their environmental data needs and the use of those data in analysis and prediction. Additionally, the COPC substructure completed an upgrade to the COPC Network that will allow for increased capacity and stage the NOAA portion of the network to connect to the future NIPRNet Federated Gateway (NFG).

During FY 2013, activities under COPC's Working Group for Cooperative Support and Backup will include the work of three joint action groups. The Joint Action Group for Operational Community Modeling (JAG/OCM) will work to enhance the implementation of ensemble efforts among the centers and expand coordination for ocean modeling implementation. The Joint Action Group for Centralized Communications Management (JAG/CCM) will work to connect the COPC Network through the NFG to mitigate the operational impacts on the exchange of data between the operational processing centers. The Joint Action Group for Operational Data Acquisition for Assimilation (JAG/ODAA) will address the follow-on efforts that came out of the ODW.

### National Space Weather Program Council

Over the past year, the Federal agencies engaged in the National Space Weather Program Council (NSWP) have been working to establish closer coordination in providing space weather science, research, and services to our Nation. The NSWP agencies have agreed to enter into a more formal relationship to establish the Unified National Space Weather Capability (UNSWC) which is seeking to achieve maximum efficiency and effectiveness in the provision of space weather services, research, and technology to our customers and stakeholders. The UNSWC agreement was established by an interagency Memorandum of Understanding (MOU) among the five agencies in order to more effectively implement planning, programming, budgeting, and execution of interagency initiatives. The UNSWC is the product of interagency coordination among all nine NSWP partners that participate and contribute to the UNSWC in various ways. One of the early achievements of the UNSWC initiative has been the launch of a new internet website called the National Space Weather Portal (www.spaceweather.gov/portal). The 'portal' provides one-stop access to all space weather services and supporting research activities provided by the Federal government. Additionally, the portal will serve as the internationally recognized entry point to U.S. space weather support and services, encompassing the ongoing contributions of the NSWP member agencies.

In April 2012, the NSWP provided OSTP an update to the report entitled, *Space Weather Observing Systems: Current Capabilities and Requirements for the Next Decade*. This analysis and report provided an interagency-approved comprehensive architecture for current and future space weather observing capabilities. Findings and recommendations contained in the report will help inform the President's budget and respond to congressional interest. The results from this report were subsequently used as input to the OSTP National Earth Observing Task Force (NEO TF) Space Weather SBA. A working group of space weather subject matter experts from the NSWP agencies performed a careful translation and reanalysis of the NSWP report data into the NEO TF assessment model.

In June 2012, 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 2012 SWEF brought together about 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.

### Executive Council for Multifunction Phased Array Radar

The Multifunction Phased Array Radar (MPAR) initiative seeks to consolidate the radar surveillance missions of four agencies: DOD, DHS, DOC/NOAA, and DOT/Federal Aviation Administration (FAA), 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) implementing dual polarization on a phased array system.

MPAR risk reduction is driven by the report, *Federal Research and Development Needs and Priorities for Phased Array Radar*, published by the OFCM in 2006. This report included a research and development plan, a 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 the effectiveness of phased array radar in detecting and tracking weather and the advantages of rapid updates in early identification of severe weather signatures. While there is still more to learn from the NWRT, that radar's legacy passive array technology has serious limitations, and meaningful upgrades would involve essentially replacing the radar. In 2010, the MPAR Executive Council recommended that work proceed on an FAA/NOAA technology collaboration that could lead to a new-technology dual-polarization antenna, while continued consideration was given to a proposal to modify an Army EQ-36 transportable radar for dual polarization. These two initiatives would address the two major components of the 2011 MPAR Unified R&D Plan: Technology Development and Test and Proof of Operational Concepts, respectively.

The FAA/NOAA collaboration has evolved into FAA's NextGen Surveillance and Weather Radar Capability (NSWRC)—the FAA's program to replace terminal weather and air surveillance radars. With help from NOAA funding, the 2006 siting and cost studies have been updated and a spectrum study was completed. The program has also awarded a dual-polarization implementation study, released an RFI for an antenna study (which involved developing notional requirements for all MPAR missions), and plans to award an antenna study contract with a performance period starting in early 2013. The Working Group for MPAR has tracked the work

on this program, served as a source for resources to participate in the NSWRC Government Engineering Team, and functioned as sounding board for agency input.

At its November 7, 2011, meeting the MPAR Executive Council considered several aspects of the EQ-36 modification initiative, for which the vendor had provided a notional cost and schedule proposal. The potential for multi-agency support for the effort would be enhanced by adding surveillance (i.e., non-weather) investigations to the field experiment portfolio, and those opportunities are under consideration.

The OFCM continued to participate in Integrated Surveillance (IS) and Air Domain Awareness (ADA) activities. The IS involvement focused on enhancing MPAR visibility in the IS planning process and included participating in IS technical interchange meetings and reviewing seminal documentation produced by the fledgling Integrated Surveillance Support Office. OFCM involvement in ADA is broader. The Federal Coordinator serves as the Department of Commerce (DOC) representative on the ADA Board, where he works with the other agencies to institutionalize Air Domain Awareness as an effective interagency collaboration and secures DOC equities.

### 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.

#### Hurricane and Winter Storms Operations and Research and Interdepartmental Hurricane Conference

The ICMSSR Standing Committee on Environmental Services, Operations, and Research Needs (CESORN) oversees the Working Group for Hurricane and Winter Storms Operations and Research (WG/HWSOR).

Both civilian and military organizations comprise the multi-agency national tropical cyclone forecasting and warning system of which the National Hurricane Operations Plan (NHOP) is a key document. The WG/HWSOR is responsible for the document. This year marked the 50$^{th}$ edition of the NHOP. The working group incorporated new procedures, agreements, and changes, including a major update to aircraft reconnaissance procedures. The updated plan was published prior to the 2012 hurricane season and documented the interdepartmental effort to provide the United States and designated international recipients with forecasts, warnings, and assessments concerning tropical and subtropical weather systems.

The WG/HWSOR is also the lead for the National Winter Storms Operations Plan (NWSOP). The working group identified editorial changes to be incorporated into the plan. The updated NWSOP was published prior to the start of the 2012-2013 winter-storm season.

Each year, the OFCM hosts an Interdepartmental Hurricane Conference (IHC) to provide a forum for the Federal agencies responsible for hurricane operations and/or supporting research and development, together with representatives of user communities, to prepare for the upcoming hurricane season and to make improvements to the Nation's hurricane forecasting and warning program. The 66th IHC was held in Charleston, SC, from March 5-8, 2012. The theme was *Tropical Cyclone Operations & Research: Strength and Success through Partnerships and*

*Alliances*. With strong partnerships built over many years, 192 personnel attended, including representatives from eight Federal agencies: DHS/FEMA, DOC/NOAA/NIST, DOD/Navy/Air Force/Army Corps of Engineers, DOI/USGS, DOT/FAA, NASA, NSF, and USDA. Attendees also included representatives from academia, private industry, and the media. Key takeaways from the conference included:

- Heightened emphasis on tropical cyclone partnerships and alliances with ongoing collaborative efforts has proven vital in today's budget constrained environment. Partnership between the Air Force Reserve Command's 53rd Weather Reconnaissance Squadron (53 WRS) and the NOAA Aircraft Operations Center (AOC) is key to the provision of tropical cyclone reconnaissance data to the tropical cyclone operational centers (principally the National Hurricane Center) and research agencies.
- Integrated ensemble and satellite microwave data led to a 10-20 percent improvement in rapid intensification forecast skill.
- Significant progress occurred in data assimilation and global and regional model development. For example, the Navy's COAMPS-TC research model shows promise in better forecasting tropical cyclone intensity.
- Successful research to operations efforts include the Joint Hurricane Testbed's transition of nearly half the 74 projects to operations from 2001-2011, and NOAA's Hurricane Forecast Improvement Program's (HFIP) establishment of a research to operations framework to accelerate transitions.
- Unmanned Aerial Systems (UAS) is a promising technology for improving tropical cyclone operations and research. NASA will employ two Global Hawk UASs in this year's Hurricane and Severe Storm Sentinel (HS3) experiment.
- Better visual displays of storm surge forecast products that include integration of ensemble models and techniques, and increased coordination among agencies (including social scientists) with added focus on feedback from emergency managers and the public are needed.

### Committee on Environmental Services, Operations, and Research Needs

CESORN covers a wide range of basic meteorological services and supporting research. Areas for coordination vary from year to year based on agency interests and needs.

#### Disaster Impact Assessments and Plans: Weather and Water Data

Data relevant to disasters acquired from the many observing systems often do not provide data coverage sufficient to adequately document the impacts of a major storm or flood or enable understanding of small-scale, localized processes. As a result, conventional observations are supplemented by *post-storm surveys and studies* of impact features such as flood marks and wind damage to fill information gaps and obtain more complete spatial coverage. These efforts contribute to the determination of the intensity and magnitude of storms and may support Presidential disaster declarations. They may also be used to validate emergency management and hurricane storm surge models, update FEMA Flood Insurance Rate Maps, revise building materials and construction standards, and improve forecasting models. Further, the National Institute of Science and Technology and various state agencies use the data for purposes such as improving building codes and construction practices.

To improve the efficiency of agency data collection efforts and promote sharing of data within an organized, interagency disaster impact assessment process, the Federal Coordinator established the Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (WG/DIAP) in 2010. Tasked to update the 2003 *National Post-Storm Data Acquisition Plan*, the WG/DIAP published the *National Plan for Disaster Impact Assessments: Weather and Water Data* (NPDIA) in October 2010. 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.

Using this plan in the days leading up to and after the landfall of Hurricane Isaac, there was remarkable response and coordination across the membership of the WG/DIAP. Participating Federal and academic teams deployed mobile sensors and instrumentation for collecting wind, storm surge, and other water level and wave data.

In FY 2013, the OFCM will continue to coordinate post-storm data acquisition surveys in response to natural disasters and agency requirements, including aerial support from the Civil Air Patrol (CAP). Under a three-year Memorandum of Agreement and an FY 2013 funding agreement between the OFCM and the U.S. Air Force for reimbursable support, the CAP will fly missions in support of glacial lake damming assessments in Alaska, tornado damage assessments, and severe flooding.

### Urban Meteorology and Atmospheric Transport and Diffusion R&D

On July 17, 2012, the OFCM cosponsored a session within the 16th annual George Mason University Atmospheric Transport and Diffusion Modeling Conference. The theme of the session was *Identifying the Research Needs and Current/Planned Research Projects within the Operational and Research Planetary Boundary Layer Interagency Community*. Subject matter experts (SME) from NOAA/NWS, DOE, and the National Center for Atmospheric Research (NCAR) participated in the session's panel discussion. The SMEs identified the following areas as operational and research priorities/requirements:

- Transitioning from planetary boundary layer (PBL) schemes to large-scale eddy simulation.
- Separating out waves from turbulence and understanding when and how to simulate internal waves degenerating into turbulence.
- Treating stable boundary layers and unstable boundary layers as separate and distinct entities.
- Increasing the capacity to observe heterogeneous boundary layers and to use these observations to improve data assimilation.
- Dealing with terrain (in all its variations) in a more appropriate way.
- Conducting a coordinated, joint field program to address the priorities/requirements listed above.

The Federal Coordinator plans to bring the results of the successful forum to the attention of the broader interagency scientific community with the goal of eliciting how best to proceed in meeting the operational and research requirements articulated at the special session.

### Committee for Integrated Observing Systems

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.

The Committee for Integrated Observing Systems (CIOS) provided the venue for responding to this report and is tracking a similar enterprise-wide effort led by the American Meteorological Society (AMS). Under the designation Network of Weather and Climate Observing Networks (NOWCON), much of the early work focused on the need to standardize metadata, and CIOS convened the Joint Action Group on Metadata, which studied the issue jointly with a similar AMS working group and jointly recommended a metadata standard for CIOS consideration.

CIOS broadened their focus in 2012 to look at upcoming GOES-R data, consider NWS observing requirements, and review issues related to observations tailored for climate applications. In a related activity, a poster entitled *Federal Cooperation Toward a Network of Weather and Climate and Weather Observing Networks* was presented at the American Geophysical Union fall meeting. The poster showed the relationship between the AMS efforts in the area, CIOS work, and the National Earth Observation Task Force initiative and how the combination of these projects should result in high-density surface weather observations discoverable and accessible from a distributed database.

Work began in 2012 on an update to *Federal Meteorological Handbook No. 1, Surface Weather Observations and Reports* to take advantage of enhanced capabilities of new instrumentation and to incorporate other changes that have been awaiting implementation. This work will continue into FY 2013. In addition, *Federal Meteorological Handbook No. 11, Doppler Radar Meteorological Observations*, is being updated and will undergo editorial review by the OFCM prior to publication in 2013.

### Unmanned Aerial Systems

Building on the successful *Exploratory Mini-workshop on the Utilization of UAS for Environmental Monitoring* conducted in February 4, 2011, the OFCM continued to make progress on UAS development and exploitation plans. At the December 16, 2011, ICMSSR meeting, the NOAA Unmanned Aerial Systems (UAS) Program Office presented a briefing on their current efforts to develop UAS capabilities to supplement NOAA's aircraft and satellite

observing platforms. This generated an action item to create an interagency approach to UAS development and utilization for environmental monitoring.

Additionally, the OFCM continues to support the activities of the OSTP Subcommittee for Unmanned Systems (SUS) under the Ocean Science and Technology Committee, which is part of the National Science and Technology Council structure. The OFCM's participation ensures that the SUS is well connected to the meteorological research and service providers and ensures effective coordination across the Federal meteorological enterprise to achieve maximum synergy.

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.

## Committee on Cooperative Research

### Tropical Cyclone Research

For additional information on tropical cyclone research, see Working Group for Hurricane and Winter Storms Operations and Research and Interdepartmental Hurricane Conference under Crosscutting Activities under the ICMSSR.

In 2007, the Joint Action Group for Tropical Cyclone Research completed the *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead*. This plan presented a common set of R&D priorities that were matched to operational requirements from the tropical cyclone forecast and warning centers. These priorities served as the baseline for NOAA's Hurricane Forecast Improvement Program (HFIP). In 2008 and 2010, the Working Group for Tropical Cyclone Research (WG/TCR) assessed agency research efforts mapped against tropical cyclone research needs and operational priorities. Through these assessments, the WG/TCR has established a successful process to:

- Keep the operational priorities updated.
- Assess and evaluate how research is contributing to meeting those priorities.
- Allow research managers to make informed decisions on future investments.
- Facilitate interagency collaboration and coordination.

During 2013, the WG/TCR will focus on completing the next assessment to be presented at the 67$^{th}$ Interdepartmental Hurricane Conference (IHC). The working group will also prepare responses to requests posed during the 66$^{th}$ IHC, where the working group was asked to explore options to mitigate impacts on tropical cyclone forecasts from a potential loss of satellite microwave imager information, and to explore how to best leverage ongoing modeling and ensemble activities to improve tropical cyclone forecasts.

### Weather Information for Surface Transportation

The OFCM continued to explore weather services and research and development (R&D) activities supporting the surface transportation community, building on its earlier publication, *Weather Information for Surface Transportation--National Needs Assessment Report.* During FY 2012, the OFCM participated in the annual meeting of the Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) and continued to support activities related to weather information and intelligent transportation systems. For FY 2013, activities include exploring planetary boundary layer forecast advances as well as coordinating with the OFCM CIOS on observing systems and activities related to improving surface transportation capabilities.

## Committee on Environmental Information Systems and Communications

FY 2013 activities planned for the Committee on Environmental Information Systems and Communications (CEISC) include continuing coordination among the agencies, regarding developing standards for environmental information. CEISC and the OFCM will work to assist in coordinating standards from the CIOS NOWCON initiative and work with the COPC to increase the sharing of international environmental data.

### Meteorological Codes

During FY 2012, the OFCM completed coordination of an update to the PIREP code and published Change 2 to *Federal Meteorological Handbook No. 12, United States Meteorological Codes and Coding Practices*. This change, which codified reporting the smell of sulfur dioxide associated with volcanic eruptions, did not require coding change and was published on a fast track to allow for early implementation. Coordination was also completed on Change 3, which addressed several other issues requiring updates. Change 3 will be implemented in FY 2013 to allow the longer lead time necessary for coding changes prior to implementation.

Work began on drafting a change to *Federal Meteorological Handbook No. 1, Surface Weather Observations and Reports*, which will be coordinated under CIOS. The effort will likely require some code changes and will continue into FY 2013.

## OFCM External Collaborations

### NAS/NRC Board on Atmospheric Sciences and Climate

The OFCM continues its mutually beneficial interactions with the National Academies' National Research Council (NRC). The Federal Coordinator participates in NRC Board on Atmospheric Sciences and Climate (BASC) strategic planning workshops, and he attends regularly scheduled meetings.

### Committee on Environment, Natural Resources, and Sustainability

***Committee on Environment, Natural Resources, and Sustainability Principals.*** The Federal Coordinator serves as a member of Committee on Environment, Natural Resources, and

Sustainability (CENRS), a committee of the National Science and Technology Council, and the OFCM participates in the work of the CENRS Subcommittee on Disaster Reduction (SDR).

### 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 2012, the OFCM presented two papers at the 92nd AMS Annual Meeting and will be involved in two presentations at the 93rd meeting in 2013.

## FY 2012 OFCM PUBLICATIONS

The publications listed in the table below were prepared in hard copy and/or were added to the OFCM's web site (www.ofcm.gov) during FY 2012.

| OFCM PUBLICATION | DATE | NUMBER |
|---|---|---|
| ***PLANS*** | | |
| National Hurricane Operations Plan<br>• WSR-88D Operations Plan for Tropical Cyclone Events<br>o 2012 RPG Software Build 12 Systems (05/14/2012)<br>▪ Operations Plan Without Dual Polarization<br>▪ Operations Plan With Dual Polarization<br>o 2012 RPG Software Build 13 Systems (07/11/2012)<br>▪ Operations Plan With Dual Polarization | May 2012 | FCM-P12-2012 |
| National Winter Storms Operations Plan | October 2012 | FCM-P13-2012 |
| Federal Plan for Cooperative Support and Backup Among Operational Processing Centers | January 2012 | FCM-P14-2012 |
| ***REPORTS*** | | |
| Summary Report of the National Operational Processing Centers Observational Data Workshops | May 2012 | FCM-R35-2012 |
| ***HANDBOOKS*** | | |
| Federal Meteorological Handbook No. 12 - United States Meteorological Codes and Coding Practices<br>(with: Change No. 1 - effective September 2006<br>Change No. 2 - effective July 2012) | December 1998 | FCM-H12-1998 |

# BASIC SERVICES

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

## OPERATIONAL PROGRAMS, INCLUDING PRODUCTS AND SERVICES

### NOAA/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), aircraft observations, 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 performance supercomputers, which provide weather, water, climate, ocean and space weather 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 among 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, Gulf of Mexico and Eastern Pacific 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 products with a focus on precipitation amount and type, winter precipitation, model diagnostics, surface pressure and frontal analysis. The Ocean Prediction Center (OPC), along with a component of NHC, issues marine forecasts for the Atlantic and Pacific oceans from the equator to the northern polar regions. 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) provides climate prediction, monitoring, and diagnostic products for timescales from weeks to years to the Nation and the global community for the protection of life and property and the enhancement of the economy. 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 coastal

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 Heat Health, and the Ultraviolet Index. 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..

### NOAA/National Environmental Satellite, Data, and Information Service

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

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

#### Polar-orbiting Operational Environmental Satellites

POES 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).

### Joint Polar Satellite System (JPSS)

JPSS is the next generation of Polar-Orbiting satellites scheduled to come online in FY 2017. NASA is the 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. The NPOESS Preparatory Project (NPP) was successfully launched from Vandenberg Air Force Base, CA on October 28, 2011. It is intended as a prototype of next-generation POES and is the highest priority for JPSS. NOAA and NASA have oversight of the ground system for NPP. 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. The GOES-R Advanced Baseline Imager (ABI) 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. A new instrument, the Geostationary Lightning Mapper (GLM), will be capable of measuring total lightning activity continuously day and night with a horizontal resolution on the order of 10 km and detection efficiency ranging between 70-90%.

To ensure user readiness, forecasters and other users must have access to prototype advanced products within their operational environment well before launch. The GOES-R Proving Ground (http://www.goes-r.gov/users/proving-ground.html) engages the National Weather Service (NWS) forecast, watch and warning community and other agency users in pre-operational demonstrations of the new and advanced capabilities to be available from GOES-R compared to the current GOES constellation. Examples of the advanced products include improved volcanic ash detection, lightning detection, 1-min interval rapid scan imagery, dust and aerosol detection, and synthetic cloud and moisture imagery. A key component of the GOES-R Proving Ground is the two-way interaction between the researchers who introduce new products and techniques and the forecasters who then provide feedback and ideas for improvements that can best be incorporated into NOAA's integrated observing and analysis operations.

GOES-R is a collaborative development and acquisition effort between NOAA and NASA. In FY 2013, the GOES-R program plans to continue instrument and spacecraft development to meet phased instrument delivery milestones which began 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 aircraft that collect environmental and geographic data essential to NOAA hurricane and other severe weather and atmospheric research and aircraft that conduct aerial surveys to forecast water supply and 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 nine aircraft are dedicated to this purpose throughout the year, providing valuable information to NOAA and the Nation. The NOAA Gulfstream, G-IV (SP) (N49RF**)**, provides scientists with a platform for the investigation of processes in the upper troposphere and lower stratosphere. With an operating ceiling of 45,000 ft, the G-IV is a critical tool for obtaining the data necessary to improve hurricane and winter storm track forecasts and for research leading to improvements in hurricane intensity forecasts.

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 promising 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 2012.

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 support international and interagency projects. Most recently the N43RF aircraft supported the FY 2012 Dynamics of the Madden-Julian Oscillation (DYNAMO) project from Diego Garcia. This project collected coordinated measurements in the atmosphere and ocean to capture process involved with the intra-seasonal variability such as the Madden-Julian Oscillation. The aircraft data will be used for evaluation and improvement of coupled atmosphere-ocean models.

### National Aeronautics and Space Administration Basic Meteorological Services

The National Aeronautics and Space Administration (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 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, and has launched a fully

redesigned GLOBE data and information system and web site in FY 2012. NASA supports innovative projects in science communication, as well as formal and informal education to stimulate Science, Technology, Engineering, and Mathematics (STEM) literacy and learning in schools and the public. NASA also supports the development of next generation workforce, such as the DEVELOP (not an acronym) Program and the Student Airborne Research Program (SARP) at the undergraduate level and the NASA's Earth System Science Fellowship Program at the graduate level.

### 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 Earth System Prediction Capability (NOAA-DOD-DOE-NSF-NASA Collaborative Project)

The ESPC program will provide a more accurate global ocean and atmospheric forecast system with longer skillful forecast times at synoptic, subseasonal, seasonal, and interannual scales through integrating and coupling global atmosphere, ocean, ice, land and near-space forecast models into an operational suite of prediction systems that reduce errors relative to the current modeling approaches. Additionally, it will develop a national common modeling architecture to improve cross-agency collaboration, and a much more efficient computational architecture to allow for real-time operational prediction. In FY 2013, common model architecture and standards will be initiated, demonstration plans will be developed, and science workshops and early benchmark testing will be conducted. The long range program goal is to advance skillful forecasts (relative to averaged climatology) from the operational capability, currently 7-10 days, to 30 days and longer.

### 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 2013, the USWRP will include 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, and the Air Force. In FY 2012, the DTC will continue to test and evaluate the Hurricane-WRF (HWRF) community model.

***Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information (Societal Impacts Program or SIP).*** The USWRP provides most of the support for SIP (http://www.sip.ucar.edu/) and will continue to do so in FY 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, to evaluate and transfer into operations, promising hurricane analysis and forecast applications developed in the research community. This testbed is located at NCEP's National Hurricane Center in Miami, Florida. The USWRP will continue to support the JHT in FY 2013.

***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 States. This project is operated in collaboration with OAR's National Severe Storms Laboratory (NSSL) and NWS's Hydrometeorological Prediction Center. In FY 2013, NASA and NOAA will begin their initial collaborative phase in preparation for jointly conducting a larger campaign in FY 2014.

***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)

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

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 its headquarters

and 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 several kilometers, using instruments such as wind profiling radars, sodars, and anemometers located at normal reading heights and on meteorological tall towers

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.

Another key component of WFIP is that private wind energy companies are sharing meteorological observations collected on tall towers and wind turbines on wind farms with NOAA. NOAA is using these data for model verification and validation, as well as assimilation into its advanced, rapidly refreshed weather models. NOAA has for several years been encouraging renewable energy companies to sign data sharing agreements under which NOAA will maintain the proprietary nature of such data, while using them for research and operational weather forecasts to reduce risk for the wind industry.

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 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 operational 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. 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 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.*** 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, the GOES-R GLM will dramatically improve NOAA's lightning observation capabilities over the open oceans where hurricanes form and intensify. The improvements in the prediction of tropical cyclone (TC) genesis and intensification have not kept pace with those for track forecasting. This is because intensity fluctuations within TCs are inherently related to small-scale internal processes, such as convection in the inner core, for which evolution can be readily detected by lightning activity. It is currently well accepted that TC inner core and outer band lightning are often associated with an imminent intensity change of the system. Therefore. the total lightning observations from GLM have the potential to provide a new reliable source of information for TC forecasting, which is currently sparse or lacking far at sea.

Research in FY 2013 will continue to focus on ways to use ground-based lightning networks, which can provide some information on lightning activity over the tropical oceans. The World Wide Lightning Locator Network (WWLLN) provides estimates of only about 10 percent of the total lightning activity, compared with what will be available from GOES-R, yet offers a first look at the forecast potential of this new data source over the open oceans. The WWLLN data has been extensively used to examine the relationships between lightning distributions/activity and TC formation and intensification in combination with other factors known to be important such as sea surface temperature, ambient mid-level relative humidity and ambient vertical wind

shear. Preliminary results for the Atlantic and east Pacific are very encouraging and show the potential for using lightning information to improve predictions of storm rapid intensification and rapid weakening, which are especially challenging forecast problems. Quantitative rapid intensification algorithms will continue to be run in real time and made available to forecasters at the National Hurricane Center for training and evaluation as part of the GOES-R Proving Ground. Work will begin on generalizing this algorithm to the western North Pacific as part of the new Pacific Region Proving Ground.

Because the lightning activity is closely related to cloud processes, it has the potential to provide new information that can be assimilated into numerical forecast models to improve the estimate of the initial state of the atmosphere. Data assimilation research will be performed using the Hurricane Weather Research and Forecast (HWRF) to optimize the methods for including lightning input.

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 GOES 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 / JPSS, but their less frequent updating makes them more suitable for longer term water monitoring. In FY 2013, 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 diagnostic nowcasting products, the Microburst Windspeed Potential Index (MWPI), and a multichannel GOES imager microburst risk product are currently experimentally generated and available to the public via the WWW. 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 2013 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 research and development in the fields of atmospheric dispersion, air quality, climate change, and boundary layer science. Key capabilities include improving approaches for predicting atmospheric dispersion of hazardous chemicals and materials; developing, evaluating, and applying air quality models; conducting research on surface energy budgets and climate variability and trends; and advancing the understanding of (and ability to predict) the behavior of the planetary boundary layer. ARL research contributions are also discussed in the Support Research section of Emergency Response and Homeland Security Services.

### Atlantic Oceanographic and Meteorological Laboratory (AOML)

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

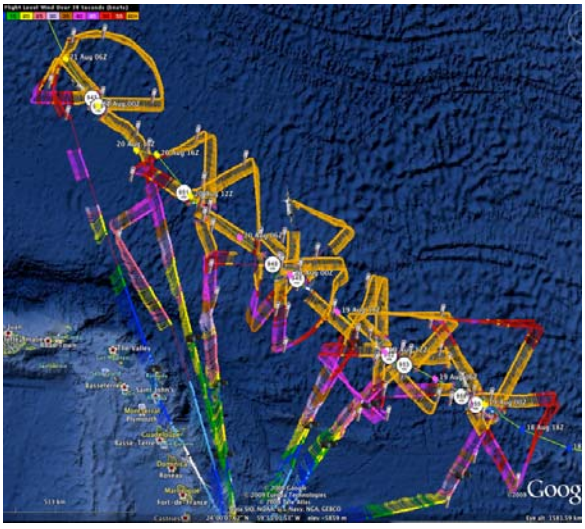
***Ocean Observing Technologies..*** In addition to the many weather-related observing systems, OAR is dedicated to improving the development, deployment, and monitoring of oceanographic-related observing technologies and related data. As part of this effort, AOML manages the deployment of drifting buoys 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.

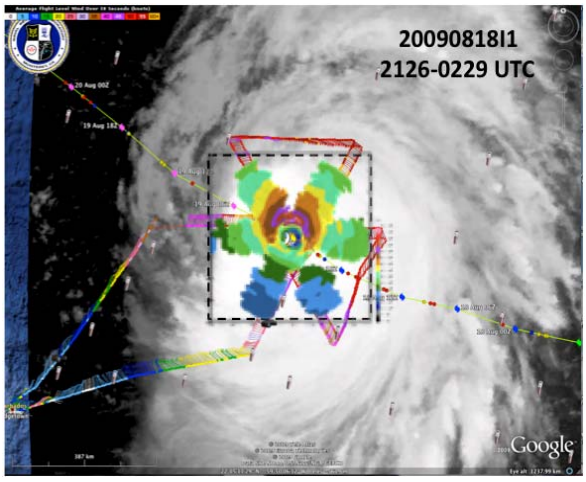
NOAA supports measurements from thermosalinographs (TSGs) which are mounted close to the water intake of research and cargo ships and continuously measure the sea surface salinity and temperature along the track of the ship. NOAA operates and maintains AMVER SEAS 2K, a

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

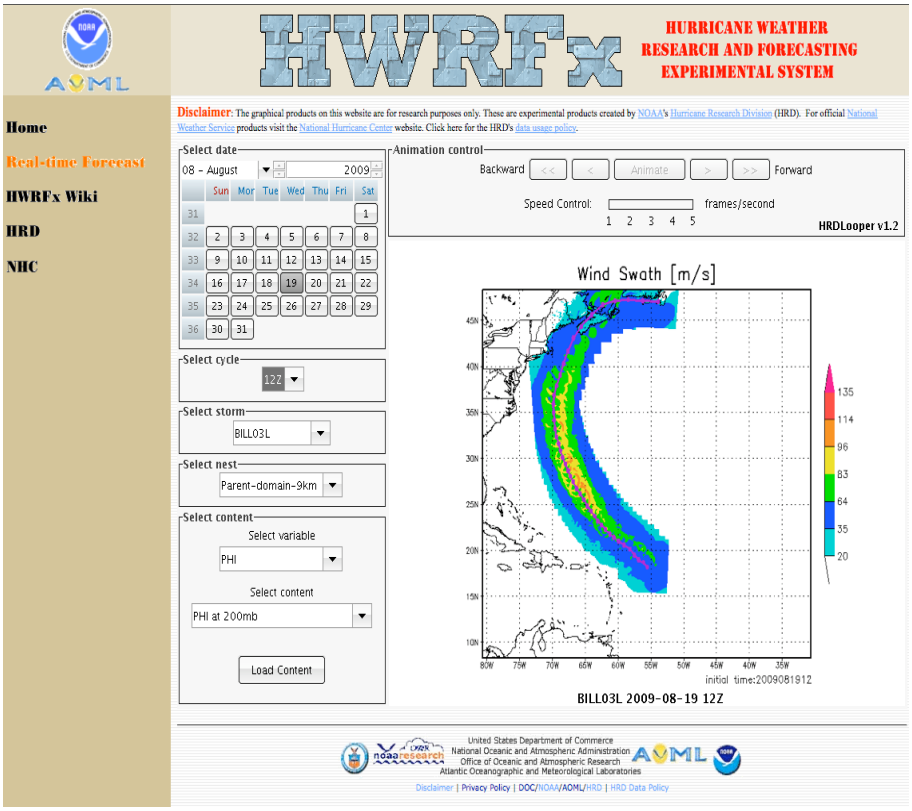





On the left is an image of the flight patterns for five consecutive back-to-back WP-3D Doppler mission around from 00Z 19 August 2009 in Hurricane Bill. On the right is a depiction of the real-time Doppler analyses for three legs on the first of the five missions showing the flight track and Doppler 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.

interaction, to name a few. These assets make HRD unique worldwide and provide NOAA with a unique capability.

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.

### 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.

ESRL/CSD scientists are leaders in the development and applications of lidar techniques for observing and characterizing the chemical and dynamical structure of the planetary boundary layer (PBL), which is key to a broad range of important issues. For example, CSD Doppler lidar studies in the vicinity of wind farms are revealing that commonly applied techniques to extrapolate surface winds to turbine hub heights are frequently not valid. To improve our understanding of energy and moisture fluxes over the ocean CSD scientists have developed a technique to stabilize a lidar beam to within better than one degree pointing accuracy for shipboard measurements. This technique is being applied to observe the wind and turbulence structure over the ocean and its role in the initiation of the Madden–Julian Oscillation, to investigate aerosol-cloud interactions in stratocumulus layers, and to evaluate the suitability of models to assess offshore wind energy potential. Airborne and ground-based lidar measurements

are affording new insights into complicated meteorological phenomena such as occurrences of nocturnal low-level jets, flows associated with mountain-valley circulations, and drainage flows in complex terrain. These observations will advance our understanding of PBL processes and structure, leading to better modeling and improved forecasting.

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 demand for finer scale meteorological services are increasingly requiring higher resolution observations to initialize and evaluate weather and climate models, applications, products, and public stakeholder needs. In response to these demands, GSD developed MADIS in partnership with NOAA/NWS to collect, integrate, quality control, and distribute observations from both NOAA and non-NOAA organizations, thus saving NOAA the costs of building tens of thousands of observing platforms. MADIS leverages partnerships with international agencies; Federal, State, and local agencies (e.g., State departments of transportation, the U.S. Department 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. As a result, MADIS provides a finer density, higher frequency observational database for use by multiple NOAA line offices and the greater meteorological community. MADIS achieved Initial Operational Capability (IOC) in 2010, with Full Operational Capability (FOC) expected by the middle of the decade.

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

### 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. Four groups at GFDL are engaged in weather research activities: Climate Dynamics and Prediction, Climate Diagnostics, 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. Research is ongoing to identify the processes that are key to determining tropical cyclone frequency.

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. A key focus of this research is to better understand the response of global and regional climated to natural and anthropogenic aerosol emissions.

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. Recent research by GFDL's Climate Diagnostics group indicates we can expect longer-lasting and more frequent heat waves during the 21$^{st}$ century as compared to the 20$^{th}$ century. GFDL's Climate Change, Variability, and Prediction group is exploring statistical methods for using coupled climate models to develop long-lead-time forecasts of seasonal hurricane activity, and experimental forecasts are available on GFDL's website. This group is exploring even longer lead-time predictions through 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 is 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. Decadal prediction experiments with the CM2.5 model are continuing to exploit NOAA's new high performance computing capability housed at DOE's Oak Ridge National Laboratory. Despite the relatively high computational 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.

### 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 five minutes for WSR-88D radar to less than one minute, producing quicker updates of data and thereby potentially increasing the lead time for tornado and microburst warnings by a substantial amount.

NSSL continues to collaborate 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 2012, as in the previous year, 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. 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. These data are now being analyzed for selected cases and will be used to study tornado development, evolution, and their associated signatures.

At the request of NWS/OST, the Office of Oceanic and Atmospheric Research (OAR) prepared a plan for a demonstration of advanced capabilities for predicting convective initiation during the spring of 2011–2012 at the Hazardous Weather Testbed (HWT), a facility jointly managed by NSSL, the NWS Storm Prediction Center, and the NWS-Norman Weather Forecast Office. The HWT is designed to accelerate the transition of promising new severe weather forecast and warning science and technology into advances in operations. The demonstration included advanced guidance products and forecaster tools.

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 ensemble 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 conducted 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. Significant advances have already been achieved with advanced data assimilation for tornadic thunderstorm events. The project is seeking to include a greater role of social science in its planning and execution.

***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 and 2011 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.

### Office of Weather and Air Quality (OWAQ)

NOAA's Office of Weather and Air Quality (OWAQ) supports the improvement of weather and air chemistry forecast information and products by funding, facilitating, coordinating and transitioning this research into useful weather and air chemistry applications. OWAQ programs provide outreach, linkage, and coordination between NOAA, other government agencies, and the

academic and private sectors, both in the U.S. and abroad. OWAQ works to ensure NOAA is optimally leveraging weather and air chemistry research capabilities. One of the programs that OWAQ administers that supports the improvement of weather and air chemistry forecasts is the U.S. Weather Research Program (USWRP)

USWRP is a NOAA program that seeks to accelerate improvements to high-impact weather forecasts by funding, facilitating, and coordinating cutting-edge research to improve weather predictions that will protect the lives and property of the American public and will inform weather-sensitive U.S. industry. USWRP works in close collaboration with NOAA scientists and academic partners to transition this research into useful weather applications. The USWRP also supports social science studies in weather and a set of related projects to provide outreach, linkage, and coordination among NOAA, other Government agencies, and the academic and private sectors, both in the U.S. and abroad. Within NOAA, the OWAQ Program manages the overall USWRP effort in support of research for weather forecasting, societal benefits, and related weather research through projects with both internal and external partners. USWRP supports research activities that include:

***Testbeds.*** Testbeds provide an infrastructure where the latest research findings and techniques are continuously tested by scientists and evaluated by NOAA's operational forecasters. Testbed funding provides support for managing the testbed activities as well as research conducted at the testbed. Testbeds serve as an effective means of demonstrating the value of research results to NOAA operational forecasters by providing an environment in which the computer hardware and software used by forecasters is used in evaluating the utility of research results. These testbeds allow for an accelerated transfer of research results into operations. In FY 2012 and FY 2013, the USWRP is funding the Joint Hurricane Testbed (JHT), the Hydrometeorological Testbed (HMT), the Hazardous Weather Testbed (HWT) and the Observing System Simulation Experiment (OSSE) Testbed.

***High-Resolution Numerical Model Improvements.*** Model improvements are required to support better high-impact weather, air chemistry, and flood forecasting. USWRP supports federal and university partnerships that are needed to develop techniques to quickly incorporate observations from radar (both operational and experimental), satellite, and other sources into models. USWRP activities will improve existing computer models and develop techniques to produce detailed, probabilistic forecasts so the users of this information understand the uncertainty associated with the forecast and can make more informed decisions. In FY 2012 and FY 2013 USWRP is funding research to improve the representation of aerosols in models. During the same time period USWRP is also supporting activities related to the Earth System Prediction Capability (ESPC) program to improve long range weather forecasts.

***Partnership Projects.*** To ensure that research that cannot be easily evaluated in a testbed, the USWRP funds competitive academic-NOAA research partnership projects. The projects usually take place outside of the testbed environment because of geographical limitations of the NOAA scientist and/or the researcher. The requirement of an academic-NOAA forecaster partnership still ensures that the project will benefit from the expertise of both the academic community and NOAA forecasters and will ultimately have a direct pathway into NOAA forecast and warning operations.

***Socioeconomic Research.*** Socioeconomic research ensures that USWRP research incorporates societal needs for weather forecasts and warnings. This research provides information about the economic value of weather research as well as understanding how society uses and interprets weather information. Socioeconomic research also provides information about improving the communication of weather information to the public. In FY 2012 and FY 2013 USWRP is funding projects selected in FY 2012 that address socioeconomic issues.

### 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 research on atmospheric aerosols and their impact on air quality and climate. In 2012, PMEL will lead the Western Atlantic Climate and Air Quality Study WACAQS) on the NOAA R/V *Ron Brown* to characterize marine and continental sources of atmospheric aerosols, atmospheric processing of those aerosols, and their impact on air quality and climate in the Northwestern Atlantic. The project will involve measurements in the Northwestern Atlantic both near shore and further offshore between the Sargasso Sea and Georges Bank with the goal of encountering a wide range of oceanic and atmospheric conditions to assess the impact of aerosols on regional climate and air quality.

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.

## NASA Supporting Research for Basic Meteorological Services

### Research in Basic Meteorology and Atmospheric Science

The FY 2013 Budget will fund research competitively selected in FY 2012 through NASA's Research Opportunities in Space and Earth Sciences 2012 (ROSES-12) grant application solicitation. Many of the research activities carried out in FY 2013 will be tasks initiated in FY 2011 and FY 2012 based on the earlier ROSES-10 and ROSES-11 solicitations. Selections based on ROSES-10 and ROSES-11 are ongoing and are addressing diverse Earth Science research areas, including biodiversity, cryospheric science, remote sensing of water quality, atmospheric composition, and interdisciplinary science.

### Short-term Prediction Research and Transition (SPoRT) Center

NASA encourages more rapid use of NASA's observations in operational weather predictions. The Short-term Prediction Research and Transition (SPoRT) center at NASA Marshall Space Flight Center is chartered to partially fulfill this research to operation transition activity. The

SPoRT center has become NASA's primary research and operation transition interface with the National Weather Service for short-term weather predictions. Many NASA research data products are tested in near real time and disseminate to NOAA's weather forecast offices. NASA also funds external research proposals to collaborate with the SPoRT center to accelerate the transition of research data to at least one operational environment.

In FY2013, NASA plans to continue the investment in SPoRT and the external research projects to accelerate the transition of research data to operational environments. New proposal opportunities may be announced in FY13.

### Technology Development

Technology investments are aligned with the goals of Earth Science Division's key strategic document, NASA's *Climate Centric Architecture*. A majority of the investments are centered around the National Research Council (NRC) Decadal Survey[1] activities, but many 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 2013, 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-11 solicitations. During FY13 ESTP will begin gathering requirements for new ROSES solicitations tentatively planned for FY14.

### 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 2013 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 its own solicitations, 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 SERVIR, or Regional Visualization and Monitoring System, network and enhance its scientific capabilities across a broader set of Earth science products. SERVIR is a joint venture between

[1] NASA and its partners ask the NRC once each decade to look out ten or more years into the future and prioritize research areas, observations, and notional missions to make those observations. The last Decadal Survey was completed in 2007, entitled *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*.

NASA and USAID which provides satellite-based Earth observation data and science applications to help developing nations improve their environmental decision making.

### National Science Foundation

To improve weather forecasts and public safety, the NSF supports basic research on observational systems, analysis techniques, and understanding of phenomena. Many of NSF's grants are to single investigators or small collaborative groups working on specific topics. Examples relevant to basic meteorological services include studies into the initiation of lightning, atmospheric turbulence, and cloud microphysics. Larger efforts including major field campaigns have recently focused on tornado genesis, mechanisms leading to genesis and rapid intensification of hurricanes, and winter storms, and analyses of these data are ongoing with the aim of improving the ability of weather forecasters to relay high-impact weather information to the public. A very recent major interagency experiment, Dynamics of the Madden Julian Oscillation (DYNAMO), was conducted in the Indian Ocean and analysis of the data should shed light on the processes of the MJO, which has a significant downstream effect on the weather of the United States.

# 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

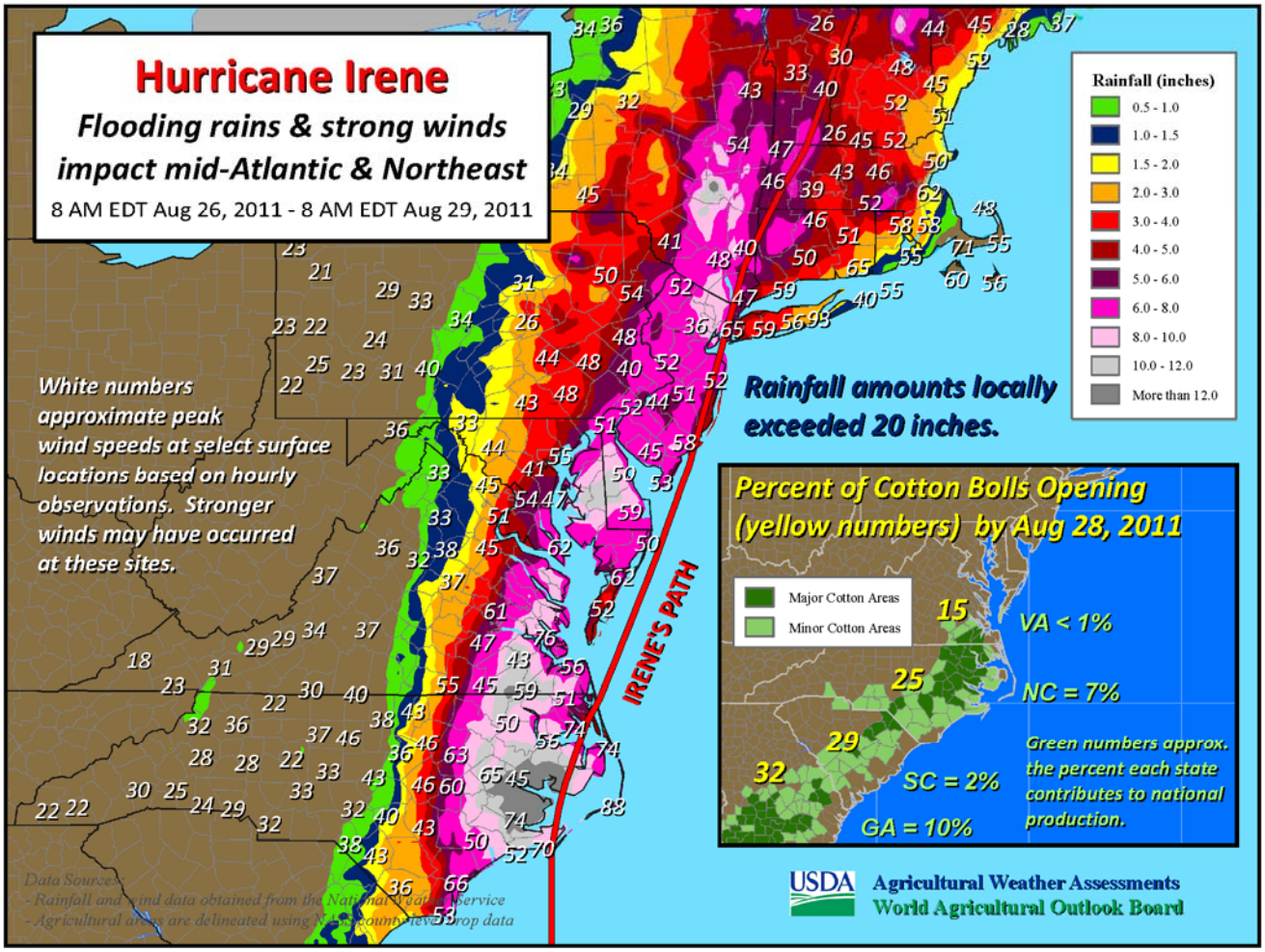
### U.S. Department of Agriculture

#### 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 outlook 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 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 in the Department for weather and climate information.

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 JAWF is to routinely collect global weather data and agricultural information to assess the impact of growing season weather conditions on crops and livestock production prospects. 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 WAOB/JAWF meteorologists utilize include surface weather observations, radar data, satellite imagery, and model output. These meteorological data are regularly imported into a Geographic Information System (GIS) along with agricultural data to facilitate global agrometeorological 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. Many of these special assessments are also prepared using GIS to overlay agricultural and meteorological data (**Figure 1**). In recent years, the NWS, National Hurricane Center (NHC), CPC, and the Hydrometeorological Prediction Center have supported WAOB/JAWF by providing an increasing number of their operational products in GIS-compatible formats. These




NOAA GIS efforts have benefited 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.

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, 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 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.

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. JAWF provides an objective procedure for converting past and present global weather information into assessments of crop-yield potential. These assessments are integrated into USDA's monthly analytical process to develop monthly foreign crop estimates of area, yield and production. These data are in turn used to estimate global supply and use (*WASDE* lockup reports).

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 NOAA/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 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), JAWF, 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://droughtmonitor.unl.edu. The USDM is released each Thursday at 8:30 a.m. Eastern time. Because the USDM is prepared in a GIS, 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 January 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 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 in Fairfax, Virginia, while a North American Drought Monitor Forum was recently held on April 18-20, 2012, in Cancun, Quintana Roo, Mexico.

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

WAOB/JAWF remains active in the World Meteorological Organization (WMO) Commission for Agricultural Meteorology (CAgM). A WAOB meteorologist is currently serving on the Management Group of the WMO CAgM, helping guide Commission efforts to improve support systems for agrometeorological services. This position helps coordinate Expert Teams responsible for reviewing the operational applications of current agrometeorological data, analytical tools, and information delivery systems and making recommendations on the procedures, methodologies, and resources necessary to improve the capability for operational applications. Additionally, WAOB continues to support the World AgroMeteorological Information Service (WAMIS), a dedicated web server that hosts agrometeorological bulletins and advisories issued by WMO Members for the global agricultural community (http://www.wamis.org/). WAOB is collaborating with other WMO Members to expand WAMIS capabilities, including the development on a web-based GIS capability that will dynamically integrate weather and climate information.

## Department of Interior

### 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

A Remote Automated Weather Station (RAWS).

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.

## SUPPORTING RESEARCH PROGRAMS AND PROJECTS

### U.S. Department of Agriculture

The Agricultural Research Service (ARS) is the principal in-house research agency for USDA and conducts research on all aspects of agriculture including crop and livestock production, natural resources and sustainable agriculture systems, and human nutrition and food safety.

Information about temperature, precipitation and wind spatial, temporal and intensity patterns are decision-making criteria for risk management of crop, livestock and ecosystem services management. Climate change research is conducted on the mitigation of the impacts of agriculture on climate, and on adapting agricultural systems for resilience to the impacts of changing climate. Weather-related research is focused on the needs of daily management decisions for water shortages and excesses, high temperature conditions, and wide swings of temperature over short periods of time. The increasing prevalence of extreme weather events, including severe storms, hail, strong wind events, and frost occurrences at almost any stage of growth, influence choice of crop or animal variety, and management actions.

Development of a strong genetic base is a foundational element of ARS weather and climate research. This includes new crop varieties that can withstand weather stresses and that will reduce susceptibility to losses from insect and disease exacerbated by the impacts of changing climate. New rangeland management systems are under investigation to incorporate drought, higher temperatures, and changes of snowpack into decision-making. Factors affecting livestock health are being examined to compensate for air temperature and moisture effects on animal health, forage quality and harmful pests.

ARS research to develop management systems builds upon the genetic base to ensure that yield potentials are reached while maintaining environmental quality for ecosystem services. Development of measurement and monitoring capacity from satellites, airborne platforms and in situ systems, and the development of process models ranging from soil-plant-atmosphere crop growth and yield models to coarse scale models for estimating hydrologic status of watersheds are objectives. Notable ARS efforts include leadership for the development and validation of algorithms for the upcoming NASA Soil Moisture Active Passive (SMAP) satellite, and the development of a satellite-based evapotranspiration algorithm currently being tested by the National Integrated Drought Information System (NIDIS). More efficient water management strategies such as irrigation scheduling with thermal remote sensing information, and the use of non-potable water ("grey-water") to augment irrigation water supplies during times of drought are being developed by ARS. Some immediate benefits are beginning to appear: the grape and wine industry is finding that reduced water usage also improves wine quality. Tillage and residue management, choice of crops during rotations, and timing of management actions are also topics of investigation.

Weather and climate data inputs and understanding of weather-driven processes are critical to the development of erosion models needed to make decisions that will reduce soil loss and degradation of water and air resources. Weather and climate 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.

The ARS experimental watershed system is transforming into the Long Term Agricultural Research (LTAR) network. A strength of the LTAR is its geographic diversity and the ability to obtain data that can be compared over time and space. The LTAR is building a data management system (DMS) that leverages experience gained from the ARS-NRCS Conservation Effectiveness Assessment Project (CEAP) DMS development.

# 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, Marine Corps, and Coast Guard) 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.

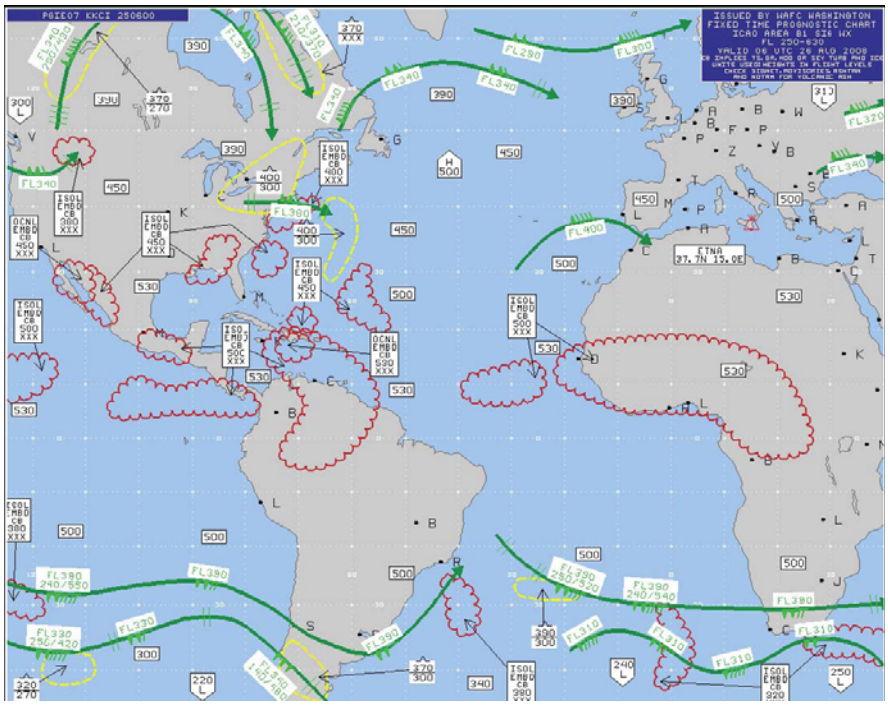
### NOAA/National Weather Service

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 World Area Forecast Center (WAFC) Washington, one of two global services, located at 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. In June 2012, ISCS will be replaced with the WAFC Internet File Service (WIFS) to provide World Area Forecast System (WAFS) products and services, as defined by ICAO Annex 3, in an Internet web-based medium.

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 by the NWS Office of Operational Systems via ISCS (until phase-out) and by AWC via WIFS 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.



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.

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 three Meteorological Watch Offices (MWO) and the two VAACs , 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

Timely and accurate weather observations and forecasts are essential to aviation safety and making the best use of aviation capacity. Pilots need to know the direction and speed of winds aloft in order to take advantage of tailwinds and minimize the effect of headwinds. They also need to know if there will be obstructions to visibility that restrict landings at their destination airport, and whether the runway is wet or dry and how that will affect braking action. Traffic

flow managers and pilots use weather observations and forecasts to determine when they need to plan alternative routes to avoid severe weather. The FAA has a lead role in collecting and distributing aviation weather data – particularly hazardous weather. The agency distributes aviation weather hazard information from its own systems and National Weather Service (NWS) computer forecast models, based on data available from FAA and NWS sensors, to develop aviation weather information for use by air traffic control facilities, pilots, airline operations centers, and other aviation-related facilities.

### Aviation Weather Systems

The FAA employs two categories of weather systems: weather sensors and weather processing/dissemination systems. FAA weather sensors include weather radars and automated surface observation systems that measure atmospheric parameters, such as surface temperature, prevailing wind speed and direction, relative humidity, and cloud bases and tops, as well as wind shear and microbursts. These weather sensors provide real-time information to air traffic facilities and to NWS centralized weather forecasting models. Weather processing systems organize, process, and distribute the sensor's observed data, matched with forecasts, and blends National Airspace System (NAS) operations with weather information. Data from multiple sensors feed numerical forecast model ensembles whose output can be disseminated and integrated in national and local processing systems to interpret broad weather trends affecting aviation operations. This information is then sent to air traffic controllers, traffic flow managers, dispatchers, and pilots in a seamless suite of weather tools that look backwards and forwards in time and along terminals, intended flight paths, flow corridors, sectors, and regions.

### Weather Sensors

Weather sensors are divided in two portfolios: Wind-Shear Detection Services (WSDS), and the Automated Surface Weather Observation Network (ASWON).

#### *Wind Shear Detection Services*

This portfolio includes the Terminal Doppler Weather Radar (TDWR), the Airport Surveillance Radar – Weather System Processor (ASR-WSP), the Next Generation Weather Radar (NEXRAD), and the Low Level Wind Shear Alert System (LLWAS). All these systems automatically detect wind shear conditions near runways and approach / departure corridors to alert controllers, who can then warn pilots of gust fronts and wind shear in the vicinity of the airport.

#### *Terminal Doppler Weather Radar*

The most sophisticated wind shear detection system is the TDWR. There are 46 operational TDWR sites serving the largest airports with the most risk of wind shear exposure. Using a three-dimensional pencil beam

A Terminal Doppler Weather Radar

and fast update rate, TDWR produce detailed weather information across the entire terminal area at the surface and aloft throughout terminal airspace. TDWR unique products include Terminal Winds (TWINDS) aloft, as well as high resolution, rapid update of storm cells with height, precipitation, surface winds, wind shear, etc. Activities are underway to address sustainment of the TDWR and the FAA is investigating whether to incorporate the TDWR functions into the NextGen Surveillance and Weather Radar Capability (NSWRC).

### *Airport Surveillance Radar–Weather System Processor (ASR-WSP)*

The ASR Model-9 and Model-11 Weather Channel detects six-level precipitation and thunderstorms that affect aircraft in flight, and the ASR Model-8 displays two-level precipitation. Airports with significant wind shear risk that have a lower volume of air traffic may be served by a lower cost alternative, such as the ASR-WSP, which processes the surveillance channel for weather from the ASR-9. The ASR-WSP detects and alerts on microbursts, wind shear, predicts arrival of gust fronts and shows precipitation intensity in a work-alike format to that of the TDWR. Activities are underway to address sustainment of these radars and the FAA is investigating whether to incorporate the ASR-WSP and ASR Weather Channel functions into the NSWRC.

### *Next Generation Weather Radar (NEXRAD)*

Development of NEXRAD occurred under a joint program of the Department of Commerce (DOC) / National Weather Service (NWS), Department of Defense (DoD), and the Federal Aviation Administration (FAA). NEXRAD are national critical assets that support (indirectly) most every user of weather information in the United States. These 160 systems are long range, Doppler weather radars that detect and produce over 120 different long-range and high-altitude weather observation products and special products, including three-dimensional areas of precipitation by type, cloud cover by height, storm cells, winds aloft, turbulence, and icing. In the short term, we are funding upgrades such as Dual Polarization (Dual Pol) and software improvements to further exploit this extensive weather capability. Dual Pol is an important addition to NEXRAD that improves detection of rain/snow mix, in-flight icing, hail, non-weather biological targets (bird strike concerns), special DoD uses, and is expected to improve the forecasting of areas where in-flight icing will occur. Working with our partner agencies, the FAA is investigating whether to incorporate planned long-range NEXRAD capabilities into the NSWRC.

### *Low Level Wind Shear Alert System (LLWAS)*

LLWAS both supplement radar systems and stands-alone at some sites. LLWAS uses an array of wind sensors located around the runway thresholds and along approach/departure corridors to measure surface wind direction and velocity. LLWAS compares wind velocity and direction, detected across the airport operations area, to determine whether wind shear events are occurring at, or near, the runways. LLWAS supplements TDWR at major airports and stands alone at other airports that do not have a TDWR or WSP. LLWAS is undergoing service life extension and the FAA is investigating whether to incorporate the functionality of these sensors into the NextGen Surface Observing Capability (NSOC).

### Automated Surface Weather Observing Network (ASWON)

The ASWON portfolio includes several surface sensors (Automated Weather Observing System (AWOS), Automated Surface Observing Systems (ASOS), Automated Weather Sensor Systems (AWSS) and Stand Alone Weather Sensing (SAWS)) that measure weather parameters on the surface and report conditions to air traffic facilities and pilots. The terminal data they collect is important to pilots and dispatchers as they prepare and file flight plans, and the overall surface data they collectively provide is vital for weather forecasting.

#### *Automated Surface Observing System (ASOS)*

The ASOS and other variants, such as the AWOS, AWSS and the SAWS system, have up to 14 individual sensors that measure surface weather data, including temperature, barometric pressure, humidity, type and amount of precipitation, cloud bases and amount of sky cover. These systems feed data directly to local air traffic control facilities and support automated broadcast of weather information to pilots and flight planning. They also provide regular, rapid updates for the National Oceanic and Atmospheric Administration (NOAA)/NWS forecast models that predict future weather conditions including adverse weather. A technical refresh is underway to keep these systems operating reliably. The FAA is investigating whether to include the functionality of these sensors under a common environment in the NSOC.

#### *Digital Altimeter Setting Indicator (DASI)*

The Digital Altimeter Setting Indicator (DASI) is a system which measures the atmospheric pressure and converts the measured pressure value into the actual sea level pressure based on the U.S. Standard Atmosphere. The value computed is known as the Altimeter Setting Indicator (ASI) value and is presented to the Air Traffic personnel in a digital format, e.g. 29.98. The DASI information is transmitted to pilots and allows them to set the barometric pressure dials of aircraft altimeters for reference.

The local DASI display panels provide a five-digit display of altimeter setting that is viewed on the Light Emitting Diode (LED) readout on the front. A keypad (or other means) on the unit enables the station altitude and a correction factor (if needed) to be entered into the system manually. Up to 10 remote displays may be accommodated.

### Weather Processing Systems

#### *Integrated Terminal Weather System (ITWS)*

ITWS consolidates weather information from automated surface observing sensors and surrounding radars, bundled with NWS forecasts and value-added algorithms such as tornado detection and wind shear prediction, to provide real-time aviation weather information for terminal control facilities. It also projects movement of thunderstorms and gust fronts up to 20 minutes into the future. Tower and Terminal Radar Approach Control (TRACON) controllers use the information to make more precise estimates of when runways should be closed and subsequently reopened. They also use the information to plan for efficient switches in terminal arrival patterns, which avoids inefficient maneuvering on taxi ways and on approach and departure, to accommodate a runway direction change as aircraft approach an airport. There are

34 ITWS Product Generators in-service at over one hundred sites (Air Traffic Control (ATC) Towers, TRACONs, Air Route Traffic Control Centers (ARTCCs) and the Air Traffic Control System Command Center (ATCSCC)) providing common aviation weather information to 75 major airports. ITWS will receive a technical refresh in the near-term. The FAA is targeting to implement the ITWS functionality in a future NextGen Weather Processor (NWP) work package.

### *Corridor Integrated Weather System (CIWS)*

CIWS gathers weather information along the busiest air traffic corridors to help air traffic specialists select the most efficient routes when they must divert traffic to avoid severe weather conditions. CIWS is a second generation evolution from ITWS and gathers high altitude weather information from NEXRAD, ITWS, satellite images, and additional NOAA/NWS sensors to widen the common weather picture in between major metropolitan areas and expand en route weather situational awareness along busy jetways and air traffic corridors to help air traffic specialists select the most efficient routes when they must divert traffic flows to avoid severe weather conditions. CIWS adds a winter weather mode, convective initiation, two hour forecast, and storm cloud height to help pilots and flow managers better decide whether to fly over or around storms. The FAA is targeting to implement the CIWS functionality in the NWP work package 1 (WP1).

### Weather And Radar Processor (WARP)

WARP provides NEXRAD precipitation intensity data to controllers' displays. WARP compiles information from many FAA, NWS and commercial weather sources for integrated display to ARTCC Traffic Management Unit (TMU) supervisors, sector controller's briefing terminals, and NAS operators of En Route Automation Modernization (ERAM), User Request and Evaluation Tool (URET), Advanced Technologies & Oceanic Procedures (ATOP), Dynamic Ocean Tracking System (DOTS), Alaska Flight Data Processor 2000 (FDP2K) and other automation and display systems and web users. WARP serves as a one-stop source for weather interpretation by the Center Weather Service Unit (CWSU) forecasting stations. Sustainment activities and WARP Enhanced Weather Dissemination (EWD) upgrades are underway and the FAA is targeting to incorporate WARP functionality into the Common Support Services – Weather (CSS-Wx) and the NWP WP1.

### *AWOS Data Acquisition System (ADAS)*

ADAS collects AWOS, ASOS and AWSS sensor data from hundreds of stations and transmits to the Weather Message Switching Center Replacement (WMSCR) for national distribution. ADAS correlates lightning ground-strike information to sensor geographic locations and passes this data to the sensor for incorporation in the One Minute Observation (OMO). Initiatives in 2012 and 2013 include support for Automated Lightning Detection and Reporting System (ALDARS) Common Lightning format and support for testing of Internet Protocol (IP) sensors. This functionality is targeted to be subsumed under a future CSS-Wx work package.

### *Aviation Digital Data Service (ADDS)*

The Aviation Digital Data Service (ADDS) makes available to the aviation community text, digital and graphical forecasts, analyses, and observations of aviation-related weather variables. ADDS is a joint effort of NCAR Research Applications Program (RAP), Global Systems Division (GSD) of NOAA's Earth System Research Laboratory (ESRL), the National Centers for Environmental Prediction (NCEP) Aviation Weather Center (AWC) and the Federal Aviation Administration (FAA).

The FAA funds and directs the continuing development of ADDS as well as other experimental products being developed by the FAA's Aviation Weather Research Program (AWRP). The results of the latest ADDS development efforts along with new experimental AWRP algorithm results can be viewed on the http://weather.aero/, the Experimental ADDS website.

The success of ADDS (averages over 10 million hits a day!) has allowed the FAA to showcase several important research initiatives including the Current and Forecast Icing Potential, the Graphical Turbulence Guidance, and the National Ceiling and Visibility Analysis. It is important to note that these products have been through thorough technical reviews and safety risk assessments before release on ADDS as operational products.

### *Weather Message Switching Center Replacement (WMSCR)*

This system, with nodes in Salt Lake City and Atlanta, collects, validates, packages, and distributes nationwide weather and Notices to Airmen (NOTAM) information. It is also a Service Oriented Architecture (SOA) publisher of Pilot Report (PIREP) and Altimeter data which distributes One-Minute Observation (OMOs) Data and Lightning Detection Data (LDD) to several NAS users. Initiatives in 2012/2013 include migration to a common platform at the Network Enterprise Management Center (NEMC) and continuing support of National Airspace Data Interchange Network (NADIN) II decommissioning. This functionality is targeted to be subsumed under a future CSS-Wx work package.

### Weather Camera Program

In the state of Alaska, lack of roads between cities, and important commercial/industrial sites make General Aviation flying (weather permitting) the only option for rapid outside access. The use of small aircraft is essential to everyday life. Limited weather information in Alaska contributes to a higher risk of accidents and can result in costly flight inefficiencies without means of backup. Without adequate local weather information about their destination airport and route of flight, pilots cannot make informed decisions on whether it is safe to fly or to continue their flight. Pictorial views of current weather conditions accessible to the aviation community in Alaska was established, and the FAA Weather Camera Program has installed aviation weather cameras as an aid to Visual Flight Rule (VFR) pilots operating in Alaska. The program funds procurement and installation of weather camera sites. Segment 1of this program is intended to fund the implementation of camera sites through Fiscal Year (FY) 2013. There are currently 177 operational camera sites in Alaska with a total goal of 221 operational sites at the end of Segment 1.

## Flight Service

Flight Service's primary role is to provide weather data, aeronautical information, and flight planning services to general aviation pilots. These services are provided by flight service specialists via phone or radio, or directly through one of two online web portals. Flight service specialists distill the complex, voluminous flight data into critical and comprehensible information tailored for a particular flight. Alternatively, pilots accessing preflight information directly through a web portal are responsible for sifting through the information on their own. The FAA delivers these services through a combination of contract vehicles for services and automation systems.

### *Operational and Supportability Implementation System (OASIS)*

OASIS is a flight service automation system operational at the 17 Flight Service Stations in Alaska since 2007 and is owned and supported by Harris Corporation. FAA Air Traffic Control Specialists operate OASIS and site level maintenance is performed by FAA Technical Operations personnel. OASIS provides integrated textual and weather graphics products, flight plan processing, emergency services, law enforcement, flight planning and regulatory information and other services as defined in FAA Job Order (JO) 7110.10. A technical refresh was completed in May 2012. The contract period of performance ends in December 31, 2014.

### *Flight Services for the 21st Century (FS21)*

FS21 is the automation system operational at the 6 Flight Service Stations operated by Lockheed Martin Corporation under the Automated Flight Service Station (AFSS) contract. FS21 provides integrated text and graphical weather products, flight planning and flight plan processing, and other services as defined in FAA JO 7110.10. The vendor also provides FAA certified pilot weather briefers to operate the system. The contract period of performance ends in September 30, 2015.

### *Direct User Access Terminal Service (DUATS)*

DUATS is an internet based weather information and flight plan processing service that allows pilots to obtain flight services without the aid of a Flight Service Specialist. The FAA's contracts for this service include two separate vendors – Data Transformation Corporation (DTC) and Computer Sciences Corporation (CSC). DUATS provides aviation weather in both textual, alphanumeric and color graphical formats according to standards defined in FAA JO 7110.10. The contract period of performance ends in 2013.

## Contract Weather Observer (CWO) Program

The Contract Weather Observer program was created by the Office of Management and Budget (OMB) in 1995, for the FAA and NWS to provide oversight and program management activities. The FAA would provide backup and augmentation to the ASOS, and the NWS would provide certification of the CWO personnel and maintenance of the ASOS program.

In February 1996, a Service Standards Policy was developed and implemented by the FAA, NWS, and industry representatives for airports having an operational ASOS. The FAA then assumed sole responsibility for providing program management and supplied operational certified Contract Weather Observers to provide back-up and augmentation of the ASOS at Service Level A and B airports. At Service Level C airports, the FAA uses Air Traffic Control personnel to perform Limited Aviation Weather Reporting System (LAWRS) duties which provide back-up for the ASOS. As of July 2012, there are 138 CWO sites and 6 Aviation Paid (A-PAID) sites (NWS Interagency Agreement) in the CWO national program.

### Next Generation Air Transportation System (NextGen)

NextGen is an umbrella term for the ongoing, wide-ranging transformation of the United States' NAS to ensure that future safety, capacity and environmental needs are met. NextGen will fundamentally change the way air traffic is managed by combining new technologies for surveillance, navigation, and communications with workforce training, procedural changes, and airfield development.

NextGen core technologies will allow introduction of new NextGen operational improvements. One of these core technologies is the Common Support Services for NAS information for which weather (CSS-Wx) is the first offering.

NextGen requires efficient consolidation of large volumes of weather observations and forecast information for processing, dissemination, and integration into decision support system algorithms to produce the more sophisticated aviation forecasts of how weather will impact NAS operations. Reduce Weather Impact (RWI) addresses these NextGen operational improvements.

#### *Common Support Services – Weather (CSS-Wx)*

In conjunction with the deployment of the System Wide Information Management (SWIM) Enterprise Service, a common information dissemination capability will be deployed for which the dissemination of weather is the first offering. This subsumes the major functions ascribed to NextGen Networked Enabled Weather (NNEW) and will over time include additional information types – aeronautical information, flight information – as these move to new information protocols and formats. We are developing the Common Support Services – Weather (CSS-Wx), extending the SWIM core services, to enhance the collection and dissemination of weather information and provide access to all users throughout the NAS. The FAA is currently performing investment analysis activities and in 2013 will make a decision on whether to implement CSS-Wx.

#### *Reduce Weather Impact (RWI)*

RWI will improve aviation weather information to support proactive planning and operations rather than adjusting for impacts after the weather has changed. RWI will enable operators to safely plan and conduct four dimensional, gate-to-gate, trajectory-based operations to not only avoid storm hazards and provide comfortable flight conditions, but also to increase overall

efficiency by improving routing/rerouting decision making. RWI provides for the development and evaluation of these concepts. There are two portfolios within RWI: Weather Observation Improvements (WOI), and Weather Forecast Improvements (WFI).

### *Weather Observation Improvements (WOI)*

A consistent and effective aviation weather observation sensor network is fundamental to NextGen. WOI will manage the evolution of the existing capability to one that possesses the optimal quantity and quality of ground, air and space based sensors. Two concept development activities are underway: the NextGen Surface Observing Capability, and the NextGen Surveillance and Weather Radar Capability.

### *NextGen Surface Observing Capability (NSOC)*

The existing surface weather observation sensor network is comprised of aging, stand-alone capabilities. Ongoing technical refreshes and Service Life Extension Programs (SLEP) can keep these sensors operating in the near to mid-term. While the current sensor network performs adequately, it is becoming increasingly costly to maintain. The NSOC will develop and evaluate methods to consolidate existing surface weather observation sensor networks, provide improved capability, and allow sensor outputs to be more universally available. Activities in FY12 and FY13 include the pre-investment analysis and proof of concept demonstrations associated with the Flexible Terminal Sensor Network (FTSN) concept. The FTSN concept addresses the terminal environment portion of the NSOC as an enterprise level solution that consolidates today's stove-pipe legacy systems into a flexible architecture that maximizes existing infrastructure with multi-use sensors to deliver a cost effective capability that preserves legacy requirements and is easily adaptable to future NextGen needs.

### *NextGen Surveillance and Weather Radar Capability (NSWRC)*

Current U.S. weather and aircraft surveillance radar networks vary in age from 10 to more than 40 years. Ongoing technical refreshes and SLEPs can keep these radars operating in the near to mid-term. However as the demands of the NAS increase, it is becoming increasingly clear that the present fleet of radars will not be capable of delivering the required functionality in the future. The FAA and NOAA have partnered together to develop and evaluate a concept that could potentially satisfy the weather and aircraft surveillance requirements of both agencies in the future. By leveraging Phased Array Radar (PAR) technology, the government is investigating the technical feasibility and affordability of consolidating and modernizing the current network of civilian radars to a single Multifunction Phased Array Radar (MPAR). Engineering studies are underway to mitigate technical risks and inform a decision in 2017 to implement a radar replacement program.

### *Weather Forecast Improvements (WFI)*

Weather Forecast Improvements supports the need to improve Air Traffic Management (ATM) decision making during adverse weather conditions and to improve the use of aviation weather

forecast information in the transformed NAS. Two main efforts are underway, the NextGen Weather Processor, and Concepts for Integration of Aviation Weather Information.

### *NextGen Weather Processor (NWP)*

The NWP establishes a common weather processing platform that will functionally replace the legacy FAA weather processor systems and host new capabilities. As input, NWP uses information such as FAA and NOAA radar and sensors and NOAA forecast models. NWP uses sophisticated algorithms to create aviation-specific current and predicted weather requiring no meteorological interpretation, for publishing via CSS-Wx. It will perform Weather Translation, which will enable the use of weather information by automated Decision-Support Tools (DST) and processes. The FAA is currently performing investment analysis activities and in 2013 will make a decision on whether to implement the NWP WP1.

### Concepts of Integration of Aviation Weather Information

Currently, NAS weather data is not well integrated into either manual procedures or automated decision-support systems. To support the predicted volume of future air traffic operations, improvements are needed. Unpredicted changes in weather are of prime concern because of the significant impact and disruption they create throughout the entire NAS. The current system does not respond well to unpredicted weather situations or to weather conditions that evolve differently than expected. This effort will address required improvements to support proactive planning operations rather than adjusting for impacts after the weather has changed. Activities in 2012 include: technical studies to identify required improvements on aviation weather information to support other solutions sets (e.g., Time-Based Flow Management (TBFM) and Collaborative Air Traffic Management (CATM)), development of metrics to assess the impact of weather in the NAS, and continuing the development of an International Civil Aviation Organization (ICAO) compliant Quality Management System (QMS). In 2013 the FAA will continue technical studies for improvements to aviation weather information, development of metrics, and development of QMS.

### 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


Volcanic ash hazards can be catastrophic to aviation operations.

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. meteorological 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. Regional plans are currently in place for Alaska, the Pacific Northwest (Washington, Oregon), and the Northern Marianas Islands (draft framework). 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. 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 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 five on-orbit sensors that monitor volcanic ash, gases, aerosols, and eruptions. The five 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; the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Terra and Aqua satellites; and the Suomi National Polar-orbiting Partnership (NPP) satellite with the Visible Infrared Imaging Radiometer Suite (VIIRS) and the Ozone Mapping and Profiler Suite (OMPS) onboard. Suomi NPP is in partnership with NOAA. NASA-built sensors on NOAA Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES) also support volcanic ash monitoring.

The NASA Science Mission Directorate, Applied Sciences Program, Disaster Area is currently responsible for developing satellite data applications for volcanic ash and is focused on research which employs these satellite measurements to improve the accuracy of aerosol dispersion model forecasts for the VAACS. The NASA Aeronautics Research Mission Directorate, Aviation Safety Program also conducts volcanic ash research. Its efforts primarily concern two areas; airborne detection and characterization of Volcanic Ash, and the determination of propulsion system tolerances and thresholds for ingesting volcanic ash for various concentrations and exposure periods. This purpose of this research is to assist in improving volcanic ash information and operating procedures for operating in or near volcanic ash environments, and to develop improved aircraft engines and systems. This also entails a number of related research efforts with both DOD and industry partners.

***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.

***U.S. AIR FORCE.*** Through its 2nd Weather Group at Offutt AFB, NE, the Air Force Weather Agency (AFWA) provides volcanic ash surveillance and analysis for DOD aviation operations worldwide. Analysts continuously monitor all active volcanoes, generating more than 4,000 bulletins per year. In addition to alert text bulletins, AFWA products include tailored satellite imagery, and graphical ash plume forecasts. It also provides the necessary expertise, information and infrastructure to facilitate critical backup for NOAA's Washington Volcanic Ash Advisory Center. Although AFWA has no operational role in civilian sector volcanic ash monitoring and forecasting, coordination with other U.S. federal agencies is required to allow DoD flying units to maintain maximum operational capability.

***Smithsonian Institution, Natural History Museum, Global Volcanism Program (GVP).*** GVP collects, catalogs, and disseminates information on volcanoes active in the Holocene (last 10,000 years). GVP supplies the aviation community with unique volcano numbers for seamless communication about volcano hazards. GVP also supplies common names, locations, and summit elevations. This information appears on aviation reports and some aviation maps---thus standardizing international communication regarding eruptive plumes and other hazards. Drawing upon information supplied by observatories and the published literature, GVP publishes an online monthly report entitled the *Bulletin of the Global Volcanism Network* that provides detailed information about volcanic systems and eruptions. The USGS and GVP partner to release a *Weekly Volcano Activity Report*. Both reports appear on the GVP website (http://www.volcano.si.edu). The website presents key geographical data for all volcanoes, eruption chronologies, geological summaries, and reports. In 2013, the website will also allow access to GVP's vast volcano database for public search and download.

## 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.

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.

### 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 facilitate collaboration and coordinate this work, VISION 100 created the JPDO, which sponsors weather, information sharing, and aviation-related study teams to facilitate longer term planning and integration of agency capabilities and to support NAS operations.

### 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 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/National Weather Service

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. The Cube will provide users more discoverable and interoperable weather data from various locations through a single access point using modern internet protocols and technologies. This Data Cube is not a physical database; instead it consists of:

a. An information technology infrastructure comparable to those already employed by other government agencies and by industry which is flexible and extensible to keep pace with user's weather information needs in a rapidly changing technological environment. The greater and easier access to NOAA weather information for aviation decision-makers enabled by the 4-D Weather Data Cube will facilitate better integration of this information into aviation users' decision-making processes and systems.

b. Aviation weather information data sets, consistent in time, space and among weather elements, providing a complete picture of how weather will impact aviation across the NAS.

c. 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. Advanced aviation forecast generation techniques and advanced tools and techniques to allow NWS meteorologists to generate aviation weather information faster and more accurately.

The Single Authoritative Source (SAS) identifies the preferred data source to be used to support collaborative air traffic management decisions. It is an optimal representation of all Air Navigation Service Provider (ANSP) required 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 used directly or translated into products depicting operational impact 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. 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 4-D Weather Data Cube will be part of an integrated multi-agency architecture for weather information dissemination. The Cube information will be available to users of the NAS and to the FAA Air Traffic Management community through Common Support Services – Weather Program (CSS-Wx), formerly known as NextGen Network Enabled Weather (NNEW). While the Cube implements common weather data services on the NOAA side, CSS-Wx will implement these common data services within the FAA enterprise, and will utilize the weather data and information from the Cube for use in weather impact decisions for aviation.

### NOAA/Office of Oceanic and Atmospheric Research

Within NOAA's Office of Oceanic and Atmospheric Research (OAR), the Global Systems Division of the Earth Science Research Laboratory (ESRL/GSD) develops and evaluates aviation weather impact variables such as icing, turbulence, ceiling and visibility, convective weather, and volcanic ash as part of its development of algorithms and decision tools for NWS forecast offices, FAA traffic managers, and commercial and civil aviation. Specifically, GSD has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques.

For NextGen, the FAA is supporting GSD in developing capability to move relevant observation and forecast information into and out of the 4D Wx Data Cube (see detailed description above, in the FAA section of Aviation Services/Supporting Research Programs and Projects). Data quantity, update frequency, timeliness, and latency are important performance considerations for this capability, which will become part of NNEW and the 4D Wx SAS (see descriptions above). GSD is working with the NWS, with funding from NOAA, to determine the best ways to populate the 4D Wx Data Cube with accurate, timely, and consistent observations and forecasts. Key areas of this effort include assessing the human role in the forecast process, evaluating the accuracy of these forecasts, development of operational forecasting concepts for the aviation impact variables, and putting all of these efforts together by creating a prototype dynamic 4D Wx Data Cube and its SAS subset.

GSD is developing and testing applications for providing Impact-based Decision Support Services (IDSS). Aviation operations in the future will require applications that allow skillful analysis, data fusion, and data mining capabilities to better analyze and interrogate large volumes of data. Integrated applications are necessary to enable forecasters to quickly determine what matters to the decision makers, translate forecast uncertainty into confidence information, and intervene in the forecast process as necessary to add value and produce official forecasts. GSD has been developing and testing concepts leading to integrated applications linking the Aviation

Weather Center (AWC) forecasts to air traffic flow restriction decisions performed by the Traffic Flow Manager (TFM). GSD has developed techniques and approaches that infuse various weather information with air route and aviation safety information, use historical forecast performance information to establish an environment for common situational awareness, and developed sophisticated data mining tools and display capabilities that allow identification of high-impact weather events.

Improvements in weather and climate prediction are tied to developing and running finer scale weather forecast models and model ensembles on increasingly powerful High-Performance Computing Systems (HPCS). However, NOAA does not have sufficient HPCS capacity to support its current research or operational requirements. Central Processing Unit-based (CPU-based) HPCS computing is growing more expensive as hundreds of thousands of CPU cores are being combined to provide increased compute capacity. These large CPU-based systems require large and expensive facilities and infrastructure to provide sufficient power and cooling ($5M for construction and $1M annually to run). Given tight federal budgets, CPU-based systems are, therefore, increasingly unaffordable. GSD is exploring the use of Graphics Processing Unit-based (GPU-based) systems, which can be 10-25 times faster than CPU-based systems, to run NWP models. By using GPU-based systems, savings to NOAA for facilities space, infrastructure, and electrical costs can be substantial.

The **National Severe Storms Laboratory (NSSL)** is participating in the effort to help quantify NOAA's support for the NextGen initiative. Planning with the FAA and the NWS began in FY 2009 and is anticipated to continue for the next several years. NSSL is also working with the FAA's AWRP to develop weather radar applications that enhance the safety and efficiency of the aviation community and the NAS. Work is focused on both convective weather and winter weather, with special attention to treating all WSR-88D radars within the continental United States as a single network. Such treatment allows NSSL to produce a single, authoritative 3D grid of radar data, combined with rain gage and satellite data for inclusion in the 4D Wx Data Cube. This Multi-Radar, Multi-Sensor (MRMS) system is currently being planned for operational implementation within the NCEP/EMC development environment as part of the future regional analysis and forecast system. Intensive research is also directed to polarimetric radar applications unique to aviation needs. Examples using WSR-88D dual-pol radar data include wintertime quantitative precipitation estimation, detection of icing (supercooled liquid water) conditions and winter precipitation type (snow, sleet, freezing raing, etc.) and data quality issues unique to FAA users. Work has also begun to bring in radar data from networks in other countries/regions to provide information in the 4D Wx Data Cube for regions outside the United States.

### 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.

## Federal Aviation Administration

The FAA Aviation Weather Research includes the Aviation Weather Research Program (AWRP) and Weather Technology in the Cockpit (WTIC) Program. The AWRP program will continue research into understanding the geophysical phenomena in the atmosphere and around airports that present hazardous conditions for aircraft operations. Among these hazards are in-flight icing, convective weather, turbulence, ceiling, visibility, volcanic ash, summer and winter storm activity, etc. Additional work is being done to improve models and in developing advanced weather radar techniques.

### Observations

#### *Liquid Water Equivalence (LWE) Rate Measurement & Reporting-Surface Snow/ Ice*

At airports in cold climates, a ground anti-icing/de-icing program is an essential pre-takeoff service. Decision making in a ground anti-icing/deicing program is the responsibility of the pilot. Pilots need to have the most accurate airport weather observation information available to support their ground anti-icing/deicing program decisions. Recent weather research has provided compelling evidence that snow precipitation intensity, which is currently determined by a visibility-based method only, can be more accurately determined by measuring the Liquid Water Equivalent (LWE) rate and providing this information as part of the airport weather observation. Pilots can use this enhanced information to more accurately determine their hold-over times. To capitalize on the federal government's investment in ASOS, a cost effective way to provide this LWE rate capability is to implement it in ASOS. The FAA is currently pursuing ways to provide this capability in ASOS. This improvement will enhance aircraft and passenger safety and support traffic flow management. The FAA is also pursuing development of a commercial LWE Rate System.

#### *Advanced Weather Radar Techniques (AWRT)*

The AWRT research focuses on monitoring and improving the quality of information derived from the Weather Surveillance Radar 88D (WSR-88D), TDWR, and Canadian and Mexican weather radar networks. To properly initialize convective weather, turbulence, icing and numerical weather prediction products it is critical that ingested weather radar data be of high quality. In Fiscal Years 12 and 13 the AWRT research will be focused on developing quality control techniques that ensure weather radar information is free from false weather returns caused by biologicals, clutter, or out of tolerance radars. Further research involves monitoring the benefits from the recently fielded WSR-88D dual polarization capability and ongoing efforts towards improving the quality of Canadian weather radar data that is being incorporated into various air traffic management tools will continue.

The AWRT research also involves techniques for mitigating gaps in individual weather radar networks via seamlessly integrating all weather radar networks together to form a high resolution, three dimensional mosaic. This work has produced the Multi Radar Multi Sensor (MRMS) capability. Operating at a thirty second update rate and 1 Kilometer (KM) resolution, in Fiscal Years (FYs) 12 and 13 the MRMS will continue to provide high resolution mosaic input to several FAA AWRP efforts, as well as Automatic Dependent Surveillance-Broadcast (ADS-B), Unmanned Aircraft Systems (UAS), Traffic Flow Management System (TFMS), and air traffic modeling and simulation research efforts at the William J. Hughes Technical Center (WJHTC).

### Forecasts and Modeling

#### *In-Flight Icing*

This research is aimed at developing improvements to in-flight icing diagnosis and forecasting with a goal of reducing the rate of aircraft icing related accidents and fatalities for aircraft operations in the NAS. Over the continental United States, the Current Icing Product (CIP) and Forecast Icing Product (FIP) have been developed to provide hourly updates of current and forecast in-flight icing conditions out to 12 hours. These products include probability and severity of icing conditions, as well as super-cooled large drop potential. CIP and FIP products are available to all NAS users on NOAA's Aviation Weather Center's (AWCs) Aviation Digital Data Service (ADDS) website which provides comprehensive user-friendly aviation weather graphics including icing, turbulence, and convection. Current research efforts include development of a current and forecast icing product for Alaska, and development of enhanced icing weather diagnosis and forecast algorithms using weather parameters including liquid water content, drop size, and temperature. The latter research effort called Model of Icing Conditions for Real-Time Operations (MICRO) will be used to produce future ice accretion products that will likely apply to a particular class of aircraft (prop, turboprop, jet, etc) for use in the NAS by pilots and flight crews in avoiding hazardous icing areas. Planned future efforts also include development of a global (oceanic routes) forecast icing product. Research to enhance efficiency and safety during winter terminal operations through the development of a prototype for Liquid Water Equivalent Rate System (LWES) specification for determining holdover times more accurate than those from currently used visibility tables was completed in FY2011. Results from this research are being incorporated into the Terminal Area Icing Weather Information System (TAIWIS), a project begun in FY 2012. The goal of the TAIWIS effort is to develop a comprehensive terminal area ground and in-flight icing weather product (for use by air traffic, flight crews, and ground de-icing operations) to provide terminal area icing weather information for operational decision making.

#### *Convective Weather*

Convective weather is a critical area of research due to the considerable impact it has on NAS operations. These storms cause significant problems in the NAS by contributing to delays, diversions and cancellations, along with well documented effects on safety and capacity. The FAA's AWRP Program seeks to address this problem by: (1) Exploring how thunderstorm information is used to make decisions and assessing the need for improved information; (2)

Increasing the fundamental understanding of how thunderstorms form, behave, and impact the NAS; and (3) Developing advanced thunderstorm analysis and predictive capabilities.

The following research projects will be underway in the 2012-2013 time frame: (1) Understand the convective forecast uncertainty needs of NAS Air Traffic Management; (2) Enhance high resolution forecast models to improve short-term convective forecasts; (3) Improve the prediction of large-scale convective storms in the 1-12 hour time frame; (4) Understand users' needs for lightning detection and improve lightning forecasting capabilities; and (5) Develop and advance convective weather hazard guidance for oceanic regions. In addition to the specific areas of research identified above, convective weather research will also support the initiatives of the Collaborative Decision Making (CDM) community and work to improve the prediction of other convective weather hazards such as hail, wind shear, and turbulence.

The AWRP also developed Consolidated Storm Prediction for Aviation (CoSPA), which is a high-resolution automated thunderstorm forecast capability. CoSPA maintains the look and feel of the Corridor Integrated Weather System, but provides seamless forecasts of precipitation and echo tops out to 8 hours for the strategic air traffic management time frame. It utilizes the 3 KM High Resolution Rapid Refresh (HRRR) model to resolve storm structure and blends the HRRR forecasts with high resolution storm extrapolation to create an integrated 8 hour forecast. It is interpreted like radar reflectivity, but also provides gridded outputs for future integration into Air Traffic Management Decision Support Tools. CoSPA was evaluated by ATM users over two summers and was found to provide useful information; changes to improve its meteorological performance were incorporated in response to user comments and an objective performance assessment. While it has been transitioned to the Program Management Organization (PMO) for proof of concept and risk mitigation planning, the FAA will consider additional research on CoSPA if collaborated with and supported by the PMO.

### *Turbulence*

This research has focused on producing a system of real-time turbulence nowcasts and probabilistic forecasts of turbulence. The method utilized in meeting these objectives is a turbulence forecasting task in conjunction with two supporting sensor tasks: one for in-situ detection of turbulence and the second for remote sensing of turbulence. The in situ task has resulted in the deployment of an aircraft-based Eddy Dissipation Rate (EDR) turbulence detection algorithm on aircraft at United Airlines and Delta Air Lines. 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 for the production of a turbulence analysis (nowcast) product.

From April 2009-January 2011, the FAA funded the EDR Proof of Concept Demo at Delta Air Lines. The Demo examined the potential safety, efficiency, and capacity benefits gained by providing enhanced turbulence forecasts and EDR information to airline dispatchers and to the flight crew via the dispatchers. A limited NAS Cost Benefits Analysis was conducted as part of this effort.

A separate effort, the Weather Technology in the Cockpit (WTIC) Turbulence/EDR Uplink Demonstration, is assessing the feasibility of using a low-cost device for the displaying of turbulence forecasts and EDR information in the cockpit for direct use by the flight crew. This task will provide a more complete Cost Benefits Analysis of the use of the turbulence data in the flight deck.

### *Ceiling and Visibility (C&V)*

This research has focused on developing automated ceiling and visibility products to support current needs and future NextGen requirements for improvements in safety and terminal area traffic flow efficiency. C&V research will provide NAS users with more accurate forecasts of ceiling and visibility conditions, both in terms of the timing of low ceilings and visibility and the forecast measurement of the ceilings and visibility. Timing and measurement then translates into impact. C&V can significantly disrupt airport and terminal operations. These range from impacting the airport acceptance rate to, in more severe cases, closing the airport. The FAA is working with the NWS to develop a procedure to inject newly developed model data into the existing NWS weather models. This development would then be used as a conduit for a technology infusion for terminal C&V forecasts, area forecasts and provide Air Navigation Service Providers (ANSPs) and users with more accurate and timely information on current and future C&V conditions. The C&V analysis will use frequent updates to closely track observed conditions and update the user display. C&V forecast information will be provided hourly in both probabilistic and deterministic form, and will support both human users and future automated decision support systems. Also developed, under AWRP, is the Helicopter Emergency Medical Service (HEMS) display tool that is operationally available for use by emergency helicopter crews to provide a quick look capability as a No-Go decision aid. New HEMS capabilities planned for FY 12 and 13 include creating a meteogram, or observation trending tool, adding a shaded relief background and the capability for line and point navigation functionality so the user can tailor to their needs.

### *Volcanic Ash Forecasts*

The FAA continues to lead the U.S.'s efforts to ensure the nation's air transportation system maintains an excellent safety record for operations in air space contaminated with volcanic ash. Following the eruption of the Icelandic volcano Eyjafjallajökull in April 2010, the FAA participated in the ICAO Volcanic Ash Task Force; the largest international task force ever assembled to develop a global safety risk management framework to determine safe levels of operation in airspace contaminated by volcanic ash and deal with the issues from large volcanic eruptions that disrupt global air transportation. That volcanic event, which lasted 39 days, caused the largest disruption to aviation since the Second World War.

The FAA is taking the lead, in cooperation with other U.S. agencies and international partners, in the following areas and initiatives:

• Development of a Concept of Operations for volcanic ash information in support of air traffic operations and management

• Development of a collaborative forecasting model to support the information exchange and collaboration between various Volcanic Ash Advisory Centers as well as Meteorological Watch Office, Air Navigation Service Providers, and Airline Operations Centers in volcanic ash cloud analysis and forecasts

• Support the initiative for the first engine test program for volcanic ash

Other efforts supported by various U.S. agencies and international partners include:

• Continued research efforts to improve volcanic ash dispersion and transport models which are key to providing improved forecasts of the location of ash clouds

• Improvements in volcano monitoring and the detection and reporting of volcano eruptions

The successful completion of these programs will result in improvements to the air transportation system which will reduce the economic impacts from large volcanic eruptions and ensure no decline in safety.

### *Model Development and Enhancement (MD&E)*

This AWRP research is targeted at developing and improving weather prediction models and data assimilation systems to better characterize the state of the atmosphere with the goal of providing superior aviation weather information to enhance NAS safety and capacity. These assimilation and prediction systems utilize all the latest weather observations and most modern supercomputers to create the most accurate and timely depiction of the future state of the weather. The future weather information output from these computer models serves as the underpinning for virtually all weather guidance beyond the first hour.

This research has been a collaborative partnership of the FAA, NOAA, NCAR, the Center for the Analysis and Prediction of Storms, the Air Force Weather Agency, and the Naval Research Laboratory to build the state-of-the-art Grid-point Statistical Interpolation (GSI) data assimilation system and Weather research and Forecast (WRF) modeling framework. A key result has been the 2012 implementation into NWS operations of the hourly-updated Rapid Refresh (RAP) weather prediction system. This system has yielded better wind forecasts and improved diagnoses and forecasts of weather hazardous to aviation, including en-route turbulence, convective weather, in-flight icing, and restricted visibility, over an expanded domain including Alaska.

### Weather Technology in the Cockpit (WTIC)

The overall objective of the NextGen - WTIC Program is to successfully accomplish a portfolio of research projects to develop, verify, and validate requirements to support airworthy standards. The projects will enable availability and improve the quality and quantity of Meteorological (MET) information available to the aircraft to enhance safety and efficiency in commercial, business, and general aviation operations and to support NextGen operational improvements.

The WTIC program addresses the need to enable better weather decision making and use of MET information in the transformed NAS. This includes identifying MET information requirements and a recommended architecture for disseminating that information to aircraft for pilot use or direct integration into NextGen cockpit decision support tools and systems. The program will define the necessary MET information and its presentation to safely and efficiently incorporate it into collaborative decision making relative to adverse weather decisions. The research projects in the WTIC portfolio are organized by four structural elements: Standards Support, Flight Deck Information, Human Factors, and Air/Ground Integration. A brief summary of a few research projects in each structural element are detailed in the following subsections.

### *Standards Support*

The WTIC program works closely with multiple RTCA committees. The most extensive support is provided to RTCA SC206 and their efforts to develop recommendations for data link architecture and the dissemination of MET information between aircraft and ground users. WTIC program standards support also includes participating in the SAE G-10 effort to develop a standard symbology for the presentation of MET information in the cockpit. The WTIC program will perform evaluations of the SAE G-10 recommended symbology.

### *Flight Deck Information*

The WTIC Wind Diagnosis project is focused on defining elements of wind quality that impact NextGen application programs and performing simulations to assess those impacts based on varying wind quality.

The Cloud Top Heights - Human over the Loop Demonstration (HOTL) will assess the impacts to decision making in a collaborative environment of providing cloud top data in oceanic and data sparse areas.

The Mobile Application project is researching MET information that provides benefits to the cockpit when presented on a mobile application. This project is also researching limitations of existing technology to support the concept of operation for this mobile application.

### *Human Factors*

The Standardization Assessment project is performing a quantitative assessment of the impacts of non-standardized MET presentations for General Aviation (GA) displays. This research consists of three groups of pilots flying a GA simulator with one of three common MET presentations. Researchers then measure variations in performance and multiple human factors parameters such as eye fixations.

A second human factors project is working with the National Aeronautics and Space Administration (NASA) to perform detailed callbacks on Aviation Safety Reporting System (ASRS) incident reports that identify weather or data linked MET information as a contributing factor.

The WTIC program is also performing research to develop inputs for improving pilot training relative to MET information and new MET technology.

### *Air/Ground Integration*

Research in this structural element includes modeling generic versions of common data links (e.g. Immarsat) to assess their bandwidth, latency, and other quality factors related to their capability to disseminate MET information.

The Uplink of Advanced Weather Radar Mosaic project is assessing the potential benefits and the feasibility of uplinking weather mosaics to the cockpit and to downlink sensor data from aircraft to enhance the quality of the mosaics.

### World Area Forecast System (WAFS)

The FAA/NWS, as a WAFS Provider State, supports the provision of global gridded data for wind, temperature and humidity in support of flight planning purposes for the International Civil Aviation Organization. Also included is the provision of, Significant Weather (SIGWX) in digital and chart-format, and the new forecasts for global gridded forecasts of icing, turbulence and cumulonimbus (Cb) clouds, as well as Operational aeronautical Meteorological (OPMET) data. A key obligation for the WAFS is the global dissemination of these products which is provided by the joint agreement between the FAA/NWS to operate the WAFS Internet World Area Forecast System File Service. There are more than 100 authorized users from the ICAO Asia/Pacific Region and Caribbean/South American Region who have access to the above products/information in support of U.S.'s responsibility to provide a flight document folder for flight planning.

### International Obligations

The FAA is the Meteorological Authority for the U.S. and establishes the requirements for meteorological services provided by the NWS to support international air navigation, as required by ICAO's Annex 3, Meteorological Services for International Air Navigation. As part of the requirements process the FAA, as a member of several ICAO meteorological groups, represents U.S. interests and strives for global harmonization of meteorological products and services. The FAA is the voting member on ICAO's World Area Forecast System Operations Group, ICAO's International Airways Volcano Watch Operations Group, ICAO's Aerodrome Meteorological Observation and Forecast Study Group, ICAO's Meteorological Warnings Study Group, and ICAO's Meteorological Aeronautical Requirements and Information Exchange Project Team.

# CLIMATE SERVICES

FOR PURPOSES OF THIS *Federal Plan*, Climate Services are specialized meteorological and hydrological services established to meet the requirements of Federal, state, and local agencies for information on the historical, current, and future state of the earth system. Climate services include observations, monitoring, assessments, predictions, and projections of the atmosphere, hydrosphere, and land surface systems.

## 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 meet the needs for climate information of their local users. Additionally, WFOs issue daily and monthly climate reports for their areas of responsibility, 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) is the largest climate data center in the world. 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 2010 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/.

Release of the 2011 Bulletin of the American Meteorological Society State of the Climate is schedued for July 2012, (23rd year). NOAA led the coordination, drafting, and communication of the *State of the Climate* Report, published with the July 2012 edition of the *Bulletin of the American Meteorological Society*. The 2011 Report is authored by 378 authors from 48 countries. NCDC scientists and graphics professionals led the editorial construction and composition of the 263-page report. NCDC and NOAA Communications led a public "rollout" of the document, with participation/quotes from NOAA Deputy Administrator Dr. Kathy Sullivan.

***Response to Extreme Climate Conditions***. The year 2011 was marked by many instances of extreme weather and climate, from violent weather and flooding during April, to ongoing drought and heat in the plains. NCDC's data, monitoring, and regional climate services efforts helped the Nation understand the scope and intensity of the events as they unfolded. According to NCDC analysis, 2011 saw at least 14 weather and climate disasters causing more than one billion dollars in damages; this was easily the most occurrences of the analysis period, since 1980. Regional efforts included biweekly constituent and media calls in the southern Plains, to provide ongoing information about the unfolding heat-and-drought disaster in the region. NCDC's regional climate services apparatus led this effort, and coordinated input and expertise from the National Weather Service, and NCDC-affiliated partners in state and regional climate centers in the region. The U.S. Drought Portal, hosted at NCDC, was able to deploy a regional pilot program in response to the episode. NCDC's monitoring program was able to quickly assess, in partnership with the NWS and regional partners, that: the violent weather in the southeast set new records for tornado activity in a season; the flooding along the Ohio, Mississippi and Missouri was historic for many locations; and that the summer 2011 heat in Oklahoma and Texas was the most intense any state in the Nation has seen since records began in 1895.

***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 established principles, 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 2012, 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, precipitation, soil moisture and temperature, and relative humidity 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 make ancillary measurements of solar radiation, surface skin temperature, and surface winds at 1.5 meters above the ground in order to aid in the quality assurance of the primary temperature and precipitation measurements made by USCRN.

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 climate analysis methods operationally 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 providing financial assistance to over twenty scientists across industry, government, and academia to continue to provide new CDRs to NOAA, 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.

The NCDC provides data, information, products and climate services to all sectors of the

economy, delivering weather and climate data and information to nearly two million customers each year for planning, operations, and minimizing risks associated with weather and climate extremes. NCDC provides access and data retrieval via the internet and responds to thousands of requests received via e-mail, phone, fax, and the mail. NCDC routinely produces operational products for climate monitoring, such as the weekly and monthly State of the Climate reports, the U.S. and the North American Drought Monitoring Reports and the Climatology for the U.S. reports. These and other climate assessments support business and government policy makers and implementers. NCDC also works very closely with various regional, state, and local stakeholders.

Approximately 3 petabytes (PB) of data are now directly accessible from NCDC's website, www.ncdc.noaa.gov. 1.285 petabytes (PB) {1,285 terabytes (TB)] of data were delivered on-line during FY 2011 (a 27-fold increase over FY 2005), with nearly 900 million hits and downloads from NCDC's website during that time. Several factors account for this increase, including: Continued infrastructure improvements at NCDC to accommodate user demand, the Climate Services Portal's continued development (www.climate.gov), and access to large volumes of Climate Forecast System Reanalysis data via the NOAA National Climate Model Portal (NCMP). NOAA climate data users and per cent data requests-retrievals are placed into four general categories: Business 44%, Public 33%, U.S. Government 12% and Academia 10%. The introduction of the climate.gov website is a major contributor to increased customer interactions with NOAA.

***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) at http://gosic.org 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

***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, and produces specialized weather-impact information for DoD and allied nations. The 14 WS provides decision-enabling products, allowing DoD command authorities to anticipate environmental impacts on all aspects of military operations worldwide. 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 the Department of Defense. 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 14 WS mission is more than just climatology; it is also forensic weather. It is about analyzing the past to help predict the future. The squadron continues to press ahead with innovation through the modernization of the Warfighter climatological toolkit by integrating GIS visualizations on its Web site and through development of GIS-based spatial and cloud climatologies. These emerging technologies 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 also collaborates with the National Climatic Data Center (NCDC) and other national climatic centers of expertise worldwide. Collocation with 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 six-month 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. Air Force Weather is enhancing its six-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.

### United States Navy

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)

The earth's climate is changing, and the most rapid changes are occurring in 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 to guide future Navy public, policy, and strategy discussions. TFCC recommends policy, strategy, and investments for the Navy regarding the Arctic and Climate Change that are consistent with existing National, Joint, and Naval guidance, including National Security Presidential Directive/ Homeland Security Presidential Directive (NSPD-66/HSPD-25), Joint Vision 2020, Sea Power 21, a Cooperative Strategy for 21st Century Seapower, Naval Operations Concept 21, The U.S. Navy's Vision for Information Dominance, Naval Oceanography 2025, and the Quadrennial Defense Review. Recent TFCC accomplishments include execution of the Navy's Arctic Roadmap and Climate Change Roadmap. Action items completed or underway include an Arctic Environmental Assessment, Arctic Capabilities-Based Assessment, Installation Vulnerability Assessment, and Identification of Arctic and Global Climate Change Research Needs. The Arctic and Climate Change Roadmaps provide holistic, chronological, science-based guidance for future Navy action from now through 2040. These investments include research for and development of a next-generation environmental prediction capability applicable to the Arctic.

### United States Geological Survey

The United States Geological Survey (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 Department of State (DOS) leadership, the United States worked to negotiate international agreements to phase out ozone-depleting substances, which are expected to lead to a recovery of the ozone layer by the middle of this century. In 2009 these treaties became the first to achieve universal ratification; 197 countries, including the United States, have ratified both the Vienna Convention and the Montreal Protocol. 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 Subcommittee on Global Change Research (SGCR) and the broader U.S. Global Change Research Program (USGCRP) and its Interagency Working Group on Climate Change Science and Technology (IWGCCST). The CENR was established in 1993 to coordinate domestic scientific programs. USGCRP 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 (from 2001-2008, USGCRP was known as the Climate Change Science Program, or CCSP). 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 and Earth observing 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 including innovative digital publications providing broad access to the NCA and its underlying information. 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.

***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.

***Paleo Climate Reconsturctions (Temparature and Precipation).*** NCDC extends the climate record backwards in time prior to the instrumental period by building an archive of Paleoclimate reconstructions (now containing over 11,000 sites) and by producing data and information products via the Applied Research Center for Paleoclimatology. The long baseline offered by Paleoclimate data is valuable in understanding the amplitude of natural climate variability and in assessing long-term trends. Paleoclimate reconstructions also reveal other aspects of the Earth System including carbon dioxide in the atmosphere (from ice core bubbles), ocean pH, and sea level rise. In 2011 the archive acquired new sea level time series, ocean pH data, and additional reconstructions of temperature spanning the past millennium. Scientists from the Lamont Doherty Earth Observatory contributed the Monsoon Drought Atlas (MADA), a gridded reconstruction of the Palmer Drought Severity Index across Asia. The MADA stands alongside the North American Drought Atlas as the two largest and most temporally extensive gridded reconstructions of hydrologic variability yet produced. The 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. The "Speleothem oxygen isotope" data set complements the gridded tree ring products by extending the record of hydrologic variability back to the Ice Age 21,000 years ago with unprecedented dating accuracy (+/- 100 years). NOAA also produced an independent reconstruction of temperature that fully overlaps the instrumental period (1880-1995), significant because it provides independent evidence of the warming trend of the past century. A new reconstruction of North America mean annual temperature extends to 1200 CE (Common Era), with improved estimates of uncertainty.

***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 the Global Climate Observing System - 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 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 and this work at the 114

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

stations in the CONUS was completed in August 2011. Some initial work on installing soil sensors in Alaska was begun in 2012 to gain experience with installing such sensors in a unique tundra environment. 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/Office of Oceanic and Atmospheric Research

The mission of climate research activities within NOAA/OAR is to monitor and understand Earth's climate system in order to predict the potential long-term changes in global climate as well as shorter-term climate variations that are of societal and economic importance. More information on OAR's climate research is available at: http://www.oar.noaa.gov/climate/.

To achieve this mission, climate research across OAR is structured to support the long-term goal of Climate Adaptation and Mitigation described in NOAA's Next-Generation Strategic Plan (NGSP). The NGSP identifies four Objectives under the Goal: (1) Improved scientific understanding of the changing climate system and its impacts; (2) Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions; (3) Mitigation and adaptation efforts supported by sustained, reliable, and timely climate services; and (4) A climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions.

To meet these Objectives, OAR's research is executed and delivered through a network of laboratories and cooperative institutes, programs, and university-based partnership activities. Broadly, OAR's laboratories and cooperative institutes contribute, both directly and indirectly, to all four Objectives. OAR's Climate Program Office (CPO) is the strategy lead for the NGSP Climate Goal, and it provides resources, programmatic oversight, and coordination to ensure NOAA's climate research activities proceed in an integrated and cost-effective manner. In these roles, CPO brings together and maintains relationships across NOAA laboratories, cooperative institutes, and university-based partners. OAR's laboratories and cooperative institutes work in

[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/

tandem with CPO to ensure NOAA meets its aim of an informed society anticipating and responding to climate and its impacts.

Specific aims of research conducted under the Goal's Objective of improved scientific understanding include:

- Describe and understand the state of the climate through sustained atmospheric and oceanic observations and research related to global distributions, trends, sources and sinks of atmospheric constituents that are capable of forcing change in the climate of the Earth
- Understand and predict climate variability and change from weeks to decades to centennial timescales
- Conduct advanced mathematical modeling of the climate and Earth systems, including natural climate variability, anthropogenic climate change, weather and hurricane forecasts, El Niño prediction, and stratospheric ozone depletion to improve the prediction of climate phenomena
- Sustain the observing systems essential for climate, oceanographic monitoring, and data management
- Conduct physical process research to advance a seamless suite of information and forecast products
- Understand how decision makers use climate information to improve the ability of society to plan for and respond to climate variability and change.

### NOAA/OAR Air Resources Laboratory

To provide a sound basis for understanding climate variability and change, the Air Resources Laboratory (ARL), in conjunction with partners, contributes to two land-based climate reference networks: the U.S. Climate Reference Network and the Regional U.S. Climate Reference Network, through the design, establishment, operation, maintenance, and analysis of these observing systems. ARL also provides scientific leadership and research for the establishment of an upper air climate reference network, called the Global Climate Observing System Reference Upper-Air Network.

ARL also analyzes daily to multi-decadal atmospheric variations measured by many types of climate observation systems, with a special emphasis on radiosonde (weather balloon) data. ARL's radiosonde research has identified important data problems and produced new, improved datasets by removing artificial, non-physical signals from weather observations. ARL uses these and other datasets to identify and characterize climate variability and trends. Through collaboration with climate modeling groups, ARL's datasets are used to evaluate global climate models.

### NOAA/OAR/Atlantic Oceanographic and Meteorological Laboratory (AOML)

In an effort to better understand and forecast climate, Atlantic Oceanographic and Meteorological Laboratory (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.

### NOAA/OAR/Earth System Research Laboratory (ESRL)

The Earth System Research Laboratory (ESRL) Chemical Sciences Division (CSD) climate 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 decision making. 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.

### NOAA/OAR/Geophysical Fluid Dynamics Laboratory

Over the last half century in general, and the last few years in particular, NOAA’s Geophysical Fluid Dynamics Laboratory (GFDL) has demonstrated world leadership in pushing the boundaries of climate prediction. Through direct participation in producing the Intergovernmental Panel on Climate Change (IPCC) 2007 Assessment and the Administration’s Climate Change Science Program Synthesis and Assessment Reports, GFDL’s premier climate science capacity and recent investment in computer model infrastructure allow NOAA to deliver

essential climate prediction information at the regional and local level and provide an invaluable and unique opportunity for the Nation to make critical progress in global change science. GFDL has delivered model output to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). Four model streams have been specifically designed for the climate integrations needed to address the major climate science challenges. All four streams are based on CM2.1, a GFDL coupled climate model with an atmospheric model resolution of 200km and an ocean model resolution of 100km. CM2.1 was considered among the highest quality models used in the previous IPCC Assessment Report, AR4, and will be used again in AR5. Model output will be submitted to the 5th Coupled Model Intercomparison Project (CMIP5) for use in AR5. The four modeling streams are:

1. Decadal prediction experiments 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.
2. Earth System Models (ESMs), emphasizing biogeochemical carbon-climate feedbacks through the use of a closed-carbon cycle. This is a new modeling stream that was not available in AR4. The atmospheric model is same as used in the CM2.1 model in AR4. The use of two ocean models in these experiments exposes the sensitivity of our models of the Earth System to different formulations of ocean processes. Oceanic and terrestrial biogeochemical cycles are modeled similarly in both ESMs.
3. Coupled climate models (CM3) with more realistic, self-consistent but complex atmospheric physics and chemistry than in CM2.1. This model includes interactive tropospheric- and stratospheric gas-phase chemistry, and aerosol microphysics including aerosol-cloud interactions, which were not present in CM2.1. Ocean model remains as in CM2.1 (viz., MOM4).
4. High-resolution atmospheric models at 50km and 25km resolution forced by future ocean states to improve our understanding of regional climate change in the 21st century, particularly how the frequency and magnitude of extreme events can change in a warming world. These models are derived from the atmospheric component of CM2.1.

GFDL scientists continue to play an active role in AR5, and in some instances lead, in: model intercomparison and model simulation analysis activities; submission of model data, quality control and archiving through the GFDL data portal, part of the AR5 model data archive (for AR5, models are documented so that their output will be assigned a digital object identifier [DOI], much like publications); analyses of the data outputs and inferences about the climate system via papers (3 papers have been submitted on CM3 alone), technical group memberships, and international research team memberships; via being selected as contributors and/or authors on the IPCC report's chapters (2 GFDL scientists are Review Editors and 3 are Lead Authors for the Working Group I Report for AR5).

GFDL has also made significant contributions, through high-resolution model experiments, to the North American Regional Climate Change Assessment Program (NARCCAP), and GFDL model experiments will also be used in creating the USGCRP's National Climate Assessment, due out in 2013.

### NOAA/OAR/Pacific Marine Environmental Laboratory

The Pacific Marine Environmental Laboratory (PMEL) contributes to the advancement our understanding of the impacts of climate variability and change through a long-term observations program that supports robust climate research. PMEL, with support from the NOAA Climate Program Office and several international partners including Japan, France, Brazil, India, Indonesia, South Africa, and China, led the effort to develop the Global Tropical Moored Buoy Array (GTMBA) and now maintains both the PIRATA and RAMA Arrays in the Tropical Atlantic and Indian Oceans, respectively. The TAO/TRITON Array, the original component of the GTMBA, has been transitioned from PMEL to NWS/National Data Buoy Center. Moored buoys in the GTMBA report daily values of surface meteorological parameters and subsurface temperatures and salinity values via Argos satellite for use by the NWS Climate Prediction Center and climate researchers world-wide. PMEL contributes to the maintenance of the global Argo Float Array, through an international partnership and in conjunction with Woods Hole Oceanographic Institution, Scripps Institute of Oceanography, the University of Washington, and AOML. PMEL scientists deploy floats, support the addition of new measurement capabilities on Argo floats, and conduct research on improving quality control of the Argo data. PMEL scientists support the OceanSITES program of global moored ocean reference stations for climate, maintaining several moored platforms in the Pacific. In conjunction with the International CLIVAR program, PMEL conducts ocean research on a global scale to monitor decadal-scale changes in a suite of physical, chemical, and biological parameters over the full water column, such as carbon dioxide uptake, ocean temperature, and circulation. PMEL climate researchers are active in the Arctic region, using atmospheric models to predict long-term sea-ice extent and providing information on potential impacts to ecosystem managers and local communities on Arctic change. PMEL scientists, working with the National Marine Fisheries Service, also conduct research on the impacts of ocean climate change on marine resources, conducting research on ocean acidification and on the impact of ocean and climate change on North Pacific fishery and marine mammal populations.

### Department of Agriculture/National Institute of Food and Agriculture

The National Institute of Food and Agriculture's (NIFA) 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 UV radiation and ozone level studies also fit into this broad global category.

Historical climate changes are derived from data gathering and modeling studies, enabling 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 represented in studies of both micro-and macro-climatic change. These involve studies dealing with the climatic impact on air quality, water quality and quantity, and agriculture waste management related to agricultural practices and forest and urban development. Studies on climatic impact on nutrient cycling and carbon sequestration and emission are supported with NIFA funds. Research is also being supported to quantify the impact of climate change on the incidence and severity of drought, extreme heat and cold, emerging plant and animal diseases and pests, new invasive species, shifting biodiversity and ecosystem services, and adaptation to these events.

The Agriculture and Food Research Initiative (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 focuses on research related to 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, environmental markets, and food safety.

### 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.

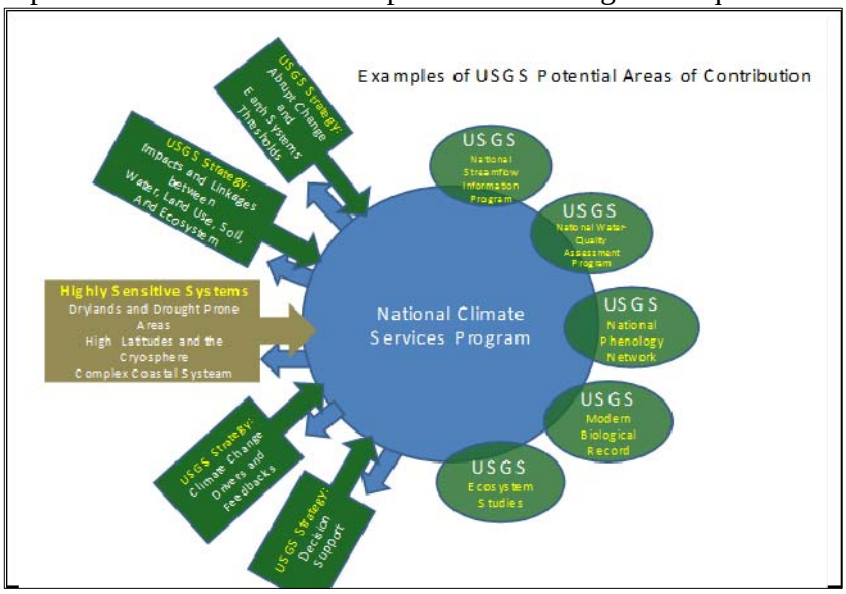
***Snow and Ice Studies.*** The USGS, in cooperation with BLM, is using a variety of remote sensing data to monitor the rapid wastage of the piedmont lobe of Bering Glacier, Alaska. Landsat, Radarsat, ICESat, and Ikonos observations show that Bering Glacier is retreating rapidly and thinning in an accelerating 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 to the right 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 decision makers. 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 United States Global Change Research Program (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 and 2013, 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*, frequent sampling in both space and time, and near-uniform accuracy and stability. NASA initiated, and in selected cases sustained for more than a decade, many global, high accuracy, well-calibrated data records, such as total solar irradiance at the top of the atmosphere; Arctic Ocean sea ice extent and thickness; Antarctic and Greenland ice-sheet thicknesses; global sea level 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 16 on-orbit satellite missions: ACRIMSAT, Aqua, Aquarius/SAC-D, Aura, CALIPSO, Cloudsat, EO-1, GRACE, Jason-1, Landsat-7, OSTM, QuikSCAT, SORCE, Suomi-National Polar-orbiting Partnership (NPP), Terra, and TRMM. Table 1 lists the climate services themes supported by these missions. On October 28, 2011, the Suomi-National Polar-orbiting Partnership mission was launched successfully from Vandenberg Air Force Base. The Suomi NPP mission serves as a bridge between NASA's Earth Observing System satellites to the next generation Joint Polar Satellite Systems, or JPSS, a National Oceanic and Atmospheric Administration (NOAA) program.

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 | Earth surface and interior, 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 |
| QuikSCAT | Jun 1999 | Climate variability and change |
| SORCE | Jan 2003 | Climate variability and change |
| Suomi NPP | Oct 2011 | Atmospheric composition; carbon cycle; climate variability and change; water cycle |
| 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. Although PARASOL has now fully exited the A-Train, GCOM-W1 (Shizuku), launched May 17, 2012 by Japan, has joined the A-Train in front of Aqua. The time separation between the front and rear of the A-Train is 11 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 5 satellite missions in development (Table 2) for launch from 2013 to 2017. LDCM and GPM are foundational missions, which the Decadal Survey by the National Research Council[4] assumed would be precursors to Decadal Survey missions. SMAP and 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. SAGE III on the International Space Station and GRACE Follow On (GRACE FO) are missions from NASA's 2010 Climate Initiative. CYGNSS is the first in the Earth Venture-class series of rapidly developed, cost-constrained small space missions. The President's FY 2012 Budget accommodates increased launch vehicle costs for SMAP and for OCO-2 and supports their selection and contract award through the Launch Services Program. The budget supports the launches of SMAP and OCO-2 in early FY 2015 and late FY2014, respectively. It also supports a dedicated launch of ICESat-2 in 2016 given the USAF termination of the prior plan for a comanifested launch with its DMSP-20. NASA continues with the pre-formulation studies, formulation, and development of other Decadal and climate missions such as DESDynI, GRACE FO, SWOT, PACE, and on pre-formulation studies for the OCO-3 instrument, CLARREO, ASCENDS, ACE, GEO-CAPE, and

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

HypIRI. The budget supports the first Earth Venture (EV) facility instrument selection in FY 2013 and subsequent solicitations every 15-18 months in addition to supporting the formulation of the CYGNSS mission and continuation of the EV-1 suborbital mission.

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

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

The climate-focused Tier-2 Decadal Survey mission SWOT for insight into the movement and distribution of Earth surface waters including both freshwater and oceans will enter formulation soon for launch by 2020. The SAGE-III instrument for flight on the International Space Station (ISS) in 2014 will continue in its implementation. The acquisition approach for the ACE mission for ocean color will be further defined and an acquisition strategy will be developed. The following activities will be undertaken or accomplished in FY 2013.

- The 2013 Senior Review, conducted at 2-year intervals, will review 13 of the 16 satellite missions (all those which are in extended operations funded by NASA: ACRIMSAT, Aqua, Aura, CALIPSO, CloudSat, EO-1, GRACE, Jason-1, OSTM, QuikSCAT, SORCE, Terra and TRMM) for continued operations and funding of core-data products in FY 2014 and FY 2015. The missions will be evaluated by a panel of recognized scientists for their contributions to research, the utility of their data products, and their cost-effectiveness in terms of technical performance and cost of mission extension.
- Over the last decade NASA launched a series of satellites that offer an unparalleled view of Earth from space. That series, known collectively as NASA's Earth Observing System (EOS), has provided striking new insights into many aspects of Earth, including its clouds, oceans, vegetation, ice, and atmosphere. However, as the EOS satellites age, a new generation of Earth-observing satellites are poised to take over.
- The Suomi National Polar-orbiting Partnership represents a critical first step in building this next-generation satellite system. Suomi NPP orbits the Earth about 14 times each day and observes nearly the entire surface. The NPP satellite continues key data records that are critical for climate change science.

  Suomi NPP carries a diverse payload of scientific instruments to monitor the planet. The 4,600-pound (2,100 kilogram) spacecraft, which is about the size of a small school bus, crosses the equator each afternoon at about 1:30 p.m. local time. It carries five key instruments: the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Ozone Mapping and Profiler Suite (OMPS), the Visible Infrared Imaging Radiometer Suite (VIIRS), and Clouds and the Earth's Radiant Energy System (CERES).

Scientists will use ATMS, a 22-channel passive microwave radiometer, to create global models of temperature and moisture profiles that meteorologists will enter into weather forecasting models. CrIS, a Michelson interferometer, will monitor characteristics of the atmosphere, such as moisture and pressure that will be used to produce improvements in both short-and-long term weather forecasting. OMPS, a suite of hyperspectral-imaging spectrometers, will measure Earth's ozone levels, particularly near the poles where ozone levels fluctuate the most. VIIRS, a 22-band radiometer, will collect visible and infrared views of Earth's dynamic surface processes, such as wildfires, land changes, and ice movement. VIIRS will also measure atmospheric and oceanic properties, including clouds and sea surface temperature. Finally, CERES, a 3-channel radiometer measuring reflected solar radiation, emitted terrestrial radiation, and total radiation, will monitor the natural and anthropogenic effects on the Earth's total thermal radiation budget.

Key science objectives and capabilities of Suomi NPP include:

- Climate change -- contribute to long-term records of global environmental data critical for understanding the dynamics of climate change
- Health of the ozone layer -- daily measurements of the atmospheric ozone layer that will determine whether the ozone layer is recovering as expected
- Natural disasters -- monitor wildfires, volcanic eruptions, snowstorms, droughts, floods, hurricanes and dust plumes
- Weather predictions -- a sounding instrument will collect information about cloud cover, atmospheric temperatures, humidity and other variables critical to accurate weather prediction
- Vegetation -- map global land vegetation and quantify changes in plant productivity to understand the global carbon cycle and monitor agricultural processes to predict and respond to food shortages and famines
- Global ice cover -- monitor changes to Earth’s sea ice, land ice and glaciers to track the pace of climate change
- Air pollution -- monitor the spread of health-sapping pollutants such as soot, particulate matter, nitrogen dioxide and sulfur dioxide
- Temperatures -- maintain a global record of atmospheric, land surface and sea surface temperatures critical to understanding the long-term dynamics of climate change
- Earth’s energy budget -- make measurements to determine how much energy is entering and exiting Earth's atmosphere

- NASA has selected an ocean wind study proposal led by the University of Michigan from among 19 submitted to the agency's Announcement of Opportunity for small spaceflight investigations of the Earth system. The proposed mission will make measurements of ocean surface winds throughout the life cycle of tropical storms and hurricanes, which could help lead to better weather forecasting.

  The competitively-selected proposal, the Cyclone Global Navigation Satellite System (CYGNSS), is led by Principal Investigator Dr. Chris Ruf of the University of Michigan,

and includes partnerships with the Southwest Research Institute of Texas, Surrey Satellite Technology of Colorado and NASA Ames Research Center.

It is the second award, and first award for space-based investigations, in the Earth Venture-class series of rapidly developed, cost-constrained projects for NASA's Earth Science Division. The award will be funded during the next five years for $151.7 million. The cost includes initial development, launch, deployment and data analysis.

The mission will use a constellation of small satellites that will be carried to orbit on a single launch vehicle. The CYGNSS data will enable scientists, for the first time, to probe key air-sea interaction processes that take place near the inner core of the storms, which are rapidly changing and play large roles in the genesis and intensification of hurricanes. The CYGNSS measurements also may provide information to the hurricane forecast community.

Once in orbit, CYGNSS's eight micro-satellite observatories will receive both direct and reflected signals from Global Positioning System (GPS) satellites. The direct signals pinpoint CYGNSS observatory positions, while the reflected signals respond to ocean surface roughness, from which wind speed is retrieved.

The new and unique contribution of CYGNSS is that it provides: 1) the first satellite-borne, all-weather, oceanic surface wind speed measurements in the inner core of tropical cyclones, and 2) post-QuikSCAT ocean wind measurement capability with enhanced diurnal sampling, wide-swath coverage, and improved performance in precipitating conditions. To meet the science goals, CYGNSS will produce high-temporal sampling of ocean surface wind speed in all precipitating conditions, including those experienced in the TC (tropical cyclone) eyewall. These wind measurements combined with the Global Precipitation Mission (GPM) rainfall measurements will allow scientists to understand the physical processes associated with hurricane genesis and rapid intensification.

The Earth Venture missions are part of NASA's Earth System Science Pathfinder program. The small, targeted science investigations complement NASA's larger research missions. In 2007, the National Research Council recommended NASA undertake these types of regularly solicited, quick-turnaround projects. The previous Earth Venture award was for five airborne investigations all of which are progressing well with initial data being collected. The first Announcement of Opportunity in the Earth Venture-Instruments series was issued earlier this year, and proposals are now under review.

Remaining activities to be undertaken in FY 2013 include:

- GPM will complete its observatory environmental testing.
- LDCM will be launched.
- SMAP will complete its System Integration Review (SIR).
- ICESat-2 will complete its Critical Design Review (CDR).
- OCO-2 will launch in July 2014. It will complete initial observatory environmental testing and enter storage. The spacecraft will be delivered in FY14 for launch.

- The GRACE-FO continuity mission will complete its Microwave Instrument Preliminary Design Review.
- SAGE-III will complete its Critical Design Review (CDR) and System Integration Review (SIR).
- SWOT will complete its KDP-A review and enter formulation (Phase A).
- CYGNSS will compete is Mission Definition Review (MDR).
- Continuation of Earth Venture-1 sustained airborne science campaigns.
- During FY 2012, the 5-year Making Earth System Data Records for Use in Research Environments (MEaSUREs) projects are coming to a close, with Earth System Data Records becoming available to the NASA communities. A second ROSES 2012 solicitation is in review with selected projects expected to commence in FY 2013.

### NASA Science Research

While hurricane track prediction has improved in recent decades, improvements in hurricane intensity prediction have lagged, primarily as a result of a poor understanding of the processes involved in storm intensity change. The Hurricane and Severe Storm Sentinel (HS3) is a five-year mission targeted to enhance our understanding of the processes that underlie hurricane intensity change in the Atlantic Ocean basin. HS3 will determine the extent to which either the environment or processes internal to the storm are key to intensity change.

The investigation objectives will be achieved using two Global Hawk Uninhabited Aerial Systems (UAS) with separate comprehensive environmental and over-storm payloads. The high Global Hawk flight altitudes allow overflights of most vertical storm convection and sampling of upper-tropospheric winds. Deployments from NASA’s Wallops Flight Facility and 30-hour flight durations will provide access to unrestricted air space, coverage of the entire Atlantic Ocean basin, and on-station times up to 10-24 hours depending on storm location. Deployments will be from mid-August to mid-September 2012-2014, with ten 30-hour flights per deployment, providing an unprecedented and comprehensive data set for approximately nine to twelve hurricanes.

HS3 is focused on the fundamental NASA Earth Science goal to "Study Earth from space to advance scientific understanding and meet societal needs" and NASA's Research Objective to "enable improved predictive capability for weather and extreme weather events." HS3 complements NASA's Weather Focus Area and Hurricane Science Research Program.

The following research activities will be undertaken or accomplished in FY 2013:

- Release request for proposals through ROSES.
- Increase supercomputing cycles to 1 quadrillion computer operations per second (petaflops) for weather and climate modeling.
- Continue IceBridge campaigns.
- Increase the number of science data products delivered to EOSDIS.

- Continue operation of ground networks for measuring time evolution of atmospheric trace constituents, including gases and aerosols.
- The Earth Venture-1 (EV-1) missions are conducting the following research:
    - The ATTREX EV-1 investigation uses one of the NASA Global Hawk UASs to investigate the physics and chemistry of the tropical upper troposphere and lower stratosphere. ATTREX held its initial test deployment in FY12 and will hold its first full science campaign in FY13.
    - The DISCOVER-AQ EV-1 investigation made measurements from aircraft and the ground of trace gases and aerosols that affect air quality in the Washington-Baltimore corridor during late June and July 2011. The airborne and ground-based measurements are being correlated with satellite remote sensing measurements to improve our ability to characterize and predict air quality. In order to characterize a variety of urban environments, similar measurement campaigns will take place in California's southern San Joaquin Valley during the last half of January and the first half of February 2013 and in Houston, Texas during September 2013.

### 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 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.

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

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.

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

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.

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.

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

### 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 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. As part of a cross-directorate and interagency effort, NSF, DOE and USDA will be funding new research projects in FY13 with a focus on decadal and regional prediction using Earth System Models. Work on the first round of awards made through this program is ongoing. Also in FY13, the NCAR/Wyoming Supercomputer will be made available for a variety of research topics, including climate modeling studies, partially satisfying the ever growing need in the climate community for new computing resources.

# 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

The mission of the Federal Emergency Management Agency (FEMA) 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

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

The IMAAC is led by the Department of Homeland Security (DHS) and supported by seven other federal departments and agencies: Department of Defense (DoD), Department of Energy (DOE), Department of Health and Human Services (HHS), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Nuclear Regulatory Commission (NRC).

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

The IMAAC produces both technical analyses and briefing products tailored for communications to non-technical decision makers. The IMAAC plots and consequence reports show hazard areas, affected populations, potential casualties and/or fatalities, damage estimates, and health effect, public protective action and worker protection levels. The IMAAC utilizes NOAA National Weather Service's meteorological observations and designated preferred model forecast for the plume models. The IMAAC may also use an in-house higher-resolution forecast model if determined to be representative or if IMAAC does not have access to the preferred forecast data.

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

### NOAA/National Weather Service

***National Tsunami Hazard Mitigation Program (NTHMP).*** The National Weather Service (NWS) has oversight responsibility for the NTHMP. The mission of the NTHMP is to work with communities in vulnerable U.S. coastal areas on preparedness activities to respond to tsunami events. 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 means of communicating weather-related warnings directly to the public.

***FEMA Integrated Public Alert and Warning System (IPAWS) and CMAS/WEA.*** The NWS pushes watches, warnings, advisories, and special statements in Common Alerting Protocol (CAP) format to the FEMA IPAWS Alert Aggregator. Starting Summer 2012, warnings that pose an "imminent threat" to the general public will be broadcast to cell phones in the threat area compatible with the Commercial Mobile Alert System (CMAS), also known as Wireless Emergency Alerts (WEA). Each CMAS/WEA message will have a maximum length of 90 characters. The message notifies the recipient of the alert type, expiration time, a brief description of the action to be taken, and name of the alert originator (i.e., NWS). All major and numerous smaller wireless carriers have opted-in to provide the CMAS/WEA service. Wireless carriers began nationwide rollout of CMAS/WEA on April 7, 2012.

Other alerting systems, including the Emergency Alert System (EAS), will be able to access NWS CAP messages in the Alert Aggregator for repackaging and/or redistribution as early as late summer 2012.

***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

***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 2013 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 2013, 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

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 21st 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.

## United States Navy

### Humanitarian Assistance and Disaster Response

Navy METOC personnel support Humanitarian Assistance and Disaster Response (HA/DR) operations aboard U.S. Navy and Coast Guard vessels. Most of the Command's personnel and assets deployed for this mission were engaged in conducting hydrographic surveys of ports of interest after a magnitude 7.0 earthquake struck southern Haiti from an epicenter located 10 miles southwest of the capital, Port-au-Prince. Hydrographic surveys are necessary in order to determine navigational hazards that could impede the egress of Navy assets involved in the relief support and enable the flow of humanitarian supplies. Personnel from the Naval Oceanographic Office conducted airborne lidar surveys of Port-au-Prince using the Compact Hydrographic Airborne Rapid Total Survey system. Port facilities and airports may be completely closed, electric power and potable water are not available to large segments of the population, delivery of food, medicine, gasoline, and other necessities severely limited. Communication systems, sanitation and sewage systems are rendered inoperable. As military and government facilities are also disrupted, the country becomes highly susceptible to aggression from competitive states or terrorist activities. Other Naval Oceanographic Office personnel aboard the naval oceanographic survey ship USNS Henson were called in to conduct port safety of navigation surveys in support of ship-to-shore humanitarian relief operations. Weather forecasts and surveys of anchorages and piers provided commanders with the status of port accessibility, ensuring accessibility to the port critical to allowing food, water, medical supplies, materials, and other support to arrive by sea.

#### Radiologic incidents

Navy provided assistance operations to support Japan in disaster relief following the 2011 Tōhoku earthquake and tsunami. US Navy's commitment to relief operations were illustrated as as an aircraft carrier positioned downwind direction of the nuclear plant to support emergency relief efforts and minimize human suffering,. One helicopter made a landing at Fukushima Airport after experiencing rotor icing and exposed some Australian and U.S. personnel to minor contamination. Dubbed Operation Tomodachi -- Japanese for "friendship" -- U.S. military assets mobilizing in the area include a wide range of equipment, air, sea, and ground capability and expertise from medical to communications to civil engineering. Yokota Air Base in Japan was instrumental in recovering airline traffic in the hours immediately following the earthquake. Yokota was used as an alternate airfield for planes that cannot land at Tokyo's Narita Airport. The air base also provided theater weather forecasts and coordinated with the Integrated Modeling and Atmospheric Assessment Center (IMAAC) operated by the Defense Threat Reduction Agency (DTRA).

### 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

In support of its national security, scientific research, and environmental stewardship missions, DOE has established, operated, and maintained operational meteorology programs at its field sites, national laboratories and offices. It has also managed various atmospheric research projects in support of emergency preparedness & response and homeland security services among other activities. With respect to these programs, Departmental sites and national laboratories collect quality-assured meteorological data, provide weather forecasting services, and develop site-specific climatology from these measurements.

Emergency response and homeland security services require characterization of various atmospheric processes that determine the fate and transport of hazardous materials released into the atmosphere. A central theme of meteorology programs is to protect public health and safety, and the environment, on and around DOE facilities by accurately measuring and characterizing

the relevant local atmospheric processes to establish real-time and forecasted atmospheric transport and diffusion estimates.

Activities at DOE sites include support to daily operations (e.g., work-force safety under hazardous weather and emergency conditions) and national defense programs; each requiring 24/7 support from well-managed meteorological programs.

### Meteorological Support to DOE Operations

Operational meteorology support programs provide daily customized meteorological monitoring and climatology services and weather forecasts for national defense projects, and nuclear safety and emergency preparedness and response programs. Each meteorological program is primarily focused on supporting emergency response, protecting the safety and health of onsite workers and the public, and environmental protection.

Operational meteorology programs are established at Argonne National Laboratory, Brookhaven National Laboratory, Idaho National Laboratory (INL), Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Nevada National Security Site (NNSS), Oak Ridge Reservation (ORR) inclusive of Y-12, and Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory and Hanford Site, Pantex Plant, Sandia National Laboratory/Albuquerque, Savannah River National Laboratory (SRNL) and Savannah River site, and the Waste Isolation Pilot Plant.

Some sites incorporate 24-hour severe weather watches to mitigate the potential adverse impacts on site operations and construction projects, property, and lives. Two sites have received a Storm Ready certification and others intend to pursue future certification. DOE-wide lightning safety initiatives are becoming integral elements of Integrated Safety Management Systems; supported by operational meteorology programs at NNSS, Hanford, Pantex, ORNL, Y-12, SRNL, and INL. Moreover, many sites employ state-of-the-art instrumentation in their meteorological monitoring networks, inclusive of vertical profilers, sound detection and ranging instruments, and sonic anemometry. At some DOE sites, observations are entered into the National Weather Service database through the Meteorological Assimilation Data Ingest System.

Large reservation DOE sites (e.g., INL, ORR, NNSS, Hanford, and SRNL); as well as several other sites are located in areas with heterogeneous surface characteristics (e.g., land-water interface, mountain-valley morphology, forests) and experience complex local weather conditions and resultant airflow trajectories. At these locations, diagnostic and prognostic characterization of local three-dimensional wind fields is vitally important to determine realistic and trustworthy consequence assessment results. For these reasons, multi-location comprehensive onsite meteorological monitoring programs are essential. ORNL has produced a comprehensive characterization of the wind fields in the Oak Ridge, TN area that is being used to fine-tune its ATD modeling, and other sites have extensively studied site-specific atmospheric flow phenomena. Several DOE sites also use the National Oceanic and Atmospheric Administration Weather Research Forecasting tool in their emergency response prognosticative models.

### Nuclear Regulatory Commission

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

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/ Air Resources Laboratory

Air Resources Laboratory (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. ATDD also participates in the Interagency Monitoring of Protected Visual Environments (IMPROVE) program, a Federal land management and Environmental Protection Agency air quality and visibility program focused on measuring particulate matter over the United States.

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.

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.

### Department of Energy

The Department of Energy (DOE) Meteorological Coordinating Council (DMCC) was established in 1994 to coordinate meteorological activities among the field offices to enhance cost effectiveness and productivity and to leverage synergistic opportunities. DOE has delegated the operation of its site/facility meteorological programs to 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

### NOAA/National Weather Service

National Oceanic and Atmospheric Administration's (NOAA) 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. A field infrastructure which includes 122 Weather Forecast Offices (WFO), 13 River Forecast Centers (RFC), the National Operational Hydrologic Remote Sensing Center (NOHRSC), 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 the loss of life and property from flooding and to meet the growing water resources service needs of our Nation. NWS hydrologic products and services support decision makers from a spectrum of service sectors including emergency management, agriculture, hydropower, reservoir management, and watershed management, river commerce, municipal and industrial water supply, and recreation.

WFOs assess and monitor the threat of flash and river flooding 24 hours a day 7 days a week to provide timely and accurate life-saving flood watches and warnings. Toward this end, WFOs integrate a spectrum of RFC, NCEP and NOHRSC guidance, Doppler weather radar (NEXRAD)-based precipitation estimates, and real-time telemetered precipitation and stream gauge observations, to provide routine river forecast services and critical, event-based decision support services. In addition, WFOs routinely conduct local outreach and education to heighten public and partner awareness of flood risks and NWS hydrologic services.

RFCs routinely generate short range (deterministic) through extended range (probabilistic) river forecasts and flash flood guidance. Information from the RFCs serves as the basis for local flood and flash flood warnings, watches, and advisories issued by the WFOs. These RFC products typically incorporate guidance from HPC, CPC, NOHRSC and the WFOs, and emphasize flooding impacts from meteorological events based on geographic area, land use, time of the year, and other factors. In order to provide objective simulations of future river flows, RFCs calibrate, operate, and verify sophisticated hydrologic models based on rainfall, soil characteristics, quantitative precipitation forecasts (QPFs), reservoir regulations, and several other variables. Some RFCs, especially those in mountainous regions, also provide water-supply volume and peak-flow forecasts based on snow pack in high elevations. These water supply forecasts are used by a wide range of decision makers, including those in agriculture,

hydroelectric dam operation and electricity generation, and water resources management. RFCs routinely coordinate with their associated WFOs, Federal water partners, stakeholders, and the HPC.

NOHRSC provides comprehensive snow observations, analyses, data sets and map products for the Nation. NOHRSC products and services are used by RFCs and WFOs to develop a variety of hydrologic products such as spring flood outlooks, water supply outlooks, river and flood forecasts, and reservoir inflow forecasts. Additionally, the NOHRSC provides and supports geographic information system (GIS) data sets and applications used by the RFCs in generating automated hydrologic forecast basin boundaries. NOHRSC products and services also support a wide variety of government and private-sector applications in water resource management, disaster emergency preparedness, weather and flood forecasting, agriculture, transportation and commerce.

Personnel at the NCEP's HPC, located in College Park, Maryland, routinely prepare a spectrum of forecast products used by the WFOs to develop local rainfall, snow, and ice forecasts and by the RFCs to develop local river and flood forecasts. HPC coordinates with RFCs, WFOs and other Federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of surface analyses and short-range forecast products used by NWS field offices and the weather enterprise.

NCEP's CPC monitors and forecasts short-term climate fluctuations and generates guidance to communicate the effects climate patterns can have on the Nation. CPC develops and produces a suite of centralized numerical climate predictions, monitoring and outlook products, assessments, and discussions. These forecast products include 6-10 day, 8-14 day, one-month, and three month outlooks which depict the probability the temperature and precipitation will be above or below normal. CPC also routinely produces a U.S. Hazards Outlook, a U.S. Seasonal Drought Outlook, and partners with the USDA and the National Drought Mitigation Center to produce the U.S. Drought Monitor. These products are used by WFOs and RFCs to enhance decision support services and serve as an input to RFC-generated, ensemble-based, extended range (probabilistic) river forecasts.

The capabilities of NWS Hydrologic Services were recently expanded through the implementation of the Community Hydrologic Prediction System (CHPS) at the 13 NWS RFCs. CHPS is a new operational framework, allowing for broad systems interoperability to support new water resources-related forecasts. It reinforces 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, and under the auspices of the Integrated Water Resources Science and Services (IWRSS) Consortium, 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 models 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 overarching goals of AHPS are to provide: a) better forecast accuracy by incorporating advanced hydrologic science into NWS models; b) more specific and timely information on fast-rising floods by using tools which make it easier to rapidly identify small basins affected by heavy rainfall and excessive runoff, and predict the extent and timing of the resulting inundation; c) new types of forecast information by incorporating enhanced techniques for quantifying forecast certainty and conveying this information in products which specify the probability of reaching various water levels; d) longer forecast horizons; e) easier-to-use products; and f) increased, more timely, and consistent access to hydrologic information. AHPS includes a suite of web-based products and information designed to support more informed decisions through timely and accurate hydrologic forecasts and warnings.

The NWS continues to implement AHPS which builds on the existing NWS infrastructure, including the Advanced Weather Information Processing System (AWIPS), NEXRAD, and CHPS. AHPS also provides Ensemble Streamflow Prediction - a capability that allows the NWS to generate extended range (probabilistic) river forecasts which quantify the forecast certainty. This information enables decision makers to apply risk-based analyses as they prepare for, and respond to, flooding and better 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 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 area warned in flash flood warnings, making them more credible and leading to more effective and efficient public response, which ultimately saves lives. AHPS also provides opportunities to improve NOAA's analysis and forecast capabilities related to coastal water conditions, through joint efforts with NOAA's National Ocean Service (NOS) and Office of Oceanic and Atmospheric Research (OAR).

***Integrated Water Resources Science and Services (IWRSS).*** Our Nation faces a spectrum of growing water resources challenges which necessitate the provision of new and enhanced services. These challenges include: a) population growth and economic development are stressing water supplies and increasing vulnerability; b) a changing climate is impacting water availability and quality and increasing uncertainty; and, c) an aging water infrastructure is forcing critical, expensive decisions.

In this era of growing challenges and reduced budgets, the collective capabilities of Federal water agencies need to be leveraged to inform and guide increasingly important water decisions. The provision of life-saving NWS forecasts and warnings and other important water resources information is dependent upon routine collaboration between Federal water agencies including NOAA's NWS, the U.S. Army Corps of Engineers (USACE), and the U.S. Geological Survey (USGS). To strengthen this relationship and enhance the quality of Federal water resources services, in May of 2011, NOAA's NWS, the USACE, and the USGS entered into a memorandum of understanding to design, develop, and implement the Integrated Water Resources Science and Services (IWRSS) program. Consisting of a consortium of federal agencies with complementary missions in water science, observation, management and prediction, IWRSS is a new business model for interagency collaboration in the information age.

The IWRSS Consortium envisions an integrated national water modeling framework and information services framework. Together these frameworks will establish a common operating picture for water, improve water modeling and synthesis, and support the production of a comprehensive, seamless and consistent suite of high-resolution tree-top-to-bedrock, summit-to-sea water resources products and information services. Toward this end, IWRSS applies a cross-cutting, multi-disciplinary systems approach to address complex water problems collaboratively. The overarching objective of IWRSS is to enable and demonstrate a broad, integrative national water resources information system to serve as a reliable and authoritative means for adaptive water-related planning, preparedness and response activities. IWRSS builds on progress made under AHPS, CHPS and other NOAA water forecasting services.

***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 many federal water agencies including: 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; the Department of Agriculture's Natural Resources Conservation Service (NRCS); and FEMA in 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 and flow observations and stage discharge relationships provided by the USGS and reservoir operation information provided by the USACE, are critical to NWS warning and forecast operations for the Nation's rivers.

### NOAA/Office of Marine and Aviation Operations

Within the NOAA/Office of Marine and Aviation Operations (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 Natural Resources Conservation Service (NRCS) measures snowpack and collects hydrometeorological data in the 12 western states. The main source of hydrometeorological data collection and analysis for NRCS is the Snow Survey and Water Supply Forecasting Program (SSWSF) managed by the National Water and Climate Center. Through the SSWSF Program, NRCS conducts snow surveys at high

elevations in the mountainous West. The data collection system includes more than 950 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 from remote sites to Master Stations located in Idaho and Utah. In Alaska, the network utilizes a satellite phone system to transmit data. The SNOTEL network 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, as well as mid-month forecasts and daily guidance for some basins beginning in December. 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 183 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 Corps of Engineers (COE) 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 COE dams and other water projects, for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. 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 COE sites provide real-time data via satellite, microwaves, meterbursts, landlines, or radio. Data from COE gage sites are available to NWS, and to other federal, state and local agencies.

### U.S. Geological Survey

#### Hydrometeorological Data Collection and Distribution

The USGS's Water Mission Area (WMA) 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 9,000 surface water sites, 2,700 ground water-level sites, and 1,500 water quality sites. Periodic records are collected at approximately 1,500 additional surface water sites, 20,000 ground water sites, and 10,300 water quality sites. Precipitation records are collected at about 800 sites.

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.

Data collected at most continuous-record USGS sites are transmitted from remote Data Collection Platforms to Wallops Island, Virginia, via a Geostationary Operational Environmental Satellite (GOES). From the

Wallops Island facility, data are rebroadcast to a domestic communication satellite (DOMSAT). Data are received from the DOMSAT by local readout ground stations (LRGS) procured by USGS. The USGS currently operates 21 LRGS which provide near-real-time data to the USGS's computerized National Water Information System (NWIS).

Near-real-time streamflow data and ancillary information are provided to NWS RFCs for river forecast points. Additional historical and real-time water resources data are available from the USGS database at NWIS web site (http://waterdata.usgs.gov/nwis/). During floods, these data are supplemented by additional flood flow measurements. For example, during the 2011 floods of the Missouri and Mississippi 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://wim.usgs.gov/stormtidemapper/stormtidemapper.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. OAR's National Severe Storms Laboratory (NSSL) will be providing multi-sensor (radar, gage, satellite), continental-scale, high-resolution analyses of Quantitative Precipitation Estimates in support of HMT.

***Storm-scale Hydrometeorology Research.*** Routine water level simulations that capture the complex interaction between waves, tides, river flows and storm surge have not been possible until now. NSSL has developed a prototype system that combines observations, weather and water models, and decision support tools to better forecast and prepare for inland and coastal floods. The National Severe Storm Laboratory (NSSL) Coastal-Inland Flood Observation and Warning (CI-FLOW) project uses the 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 and in Hurricane Irene in 2011, 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.

## Department of Agriculture

### Natural Resources Conservation Service

Within the Snow Survey and Water Supply Forecasting Program, there are a number of agency initiatives that support research and development in regards to system operations. These initiatives include model development, quality assurance tools, radio and telemetry development, SCAN support, and radio spectrum management.

## Nuclear Regulatory Commission

The Nuclear Regulatory Commission (NRC) conducts meteorological research to support licensing activities. Current research activities include 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 has been extended to consider the influence of orographic features. In addition, work has been 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 and the U.S. Army Corps of Engineers. The focus of NRC research in these areas is to accurately assess the potential hazard to safe operation of nuclear facilities from extremely rare hydrometeorological events.

# 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

#### 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 Air Force, 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

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 Weather mission statement

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 U.S. Air Force (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 World Wide 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.

Dr. Fred Lewis, Director of Air Force Weather, was the keynote speaker for the 75th Air Force Weather Anniversary held at the AFWA headquarters building Offutt Air Force Base, Neb., August 2. The scope of attendees ranged from Army Air Corps meteorologists to current AFWA Airman. (U.S. Air Force Photo by Josh Plueger/Released)

- 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. 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. Air Force 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. 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.

***Air Force Operational Climatology.*** The 14th Weather Squadron (14 WS) is stationed in Asheville, North Carolina, where it is co-located with the National Climatic Data Center, one of the environmental data centers under The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite, Data, and Information Service (NESDIS). The 14 WS mission is to support DoD climatological requirements for engineering, planning, and operations to maximize combat effectiveness. For more information on the 14th Weather Squadron and the National Climatic 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.

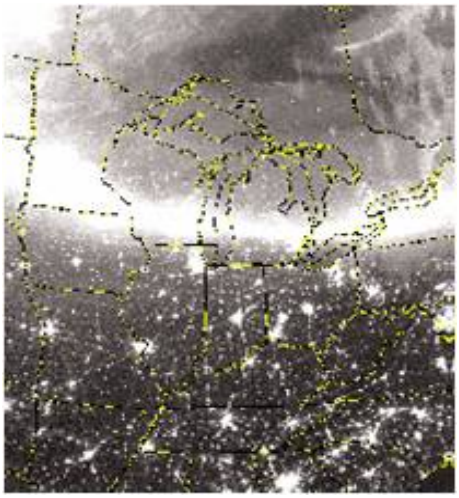
### USAF Products and Services

***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.

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).



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

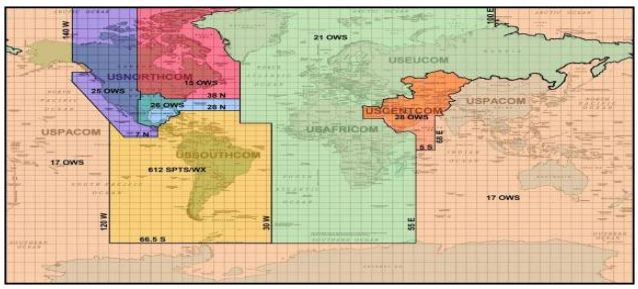
***Space Launch Support.*** USAF meteorological support for space launches is discussed in the Other Specialized Services section.

***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.

The sun tries to break through the thick clouds surrounding the WC-130J aircraft as it penetrates Tropical Storm Lee Sept. 2. The 53rd Weather Reconnaissance Squadron "Hurricane Hunters," were gathering atmospheric data to relay to the National Hurricane Center for their forecast models. (U.S. Air Force photo by Staff Sgt. Valerie Smock)

***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.

***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 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




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

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 2013, 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.

Air Force Weather personnel provide installation, garrison, and tactical weather support on a daily basis to 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). The Army provides operational weather support to Army research development, test, and evaluation (RDT&E) ranges, centers, and other research facilities using the Army Test and Evaluation Command's Meteorological Teams and USA Space and Missile Defense Command (SMDC) contractors. 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 lead 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 inter-Service 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.

### U.S. Army 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 underwent developmental 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, including weather, across all echelons. It is the Army component of the DoD Distributed Common Ground/Surface System and interoperable with Army, Joint, and Coalition Mission Command systems. DCGS-A weather services enable the Staff Weather Officer and intelligence operators to analyze and mitigate weather effects on intelligence operations, target development, and course of action selection. DCGS-A provides the actionable weather intelligence in support of tactical Army operations and resources protection. DCGS-A weather applications take advantage of Air Force weather products such as the Joint Environmental Toolkit (JET) and the Air Force Weather Web Service (AFW-WEBS) through reachback communications to supplement forward-based applications like the Integrated Weather Effects Decision Aid (IWEDA) and Weather Running Estimate (WRE). IWEDA allows Warfighters to display the effects of weather phenomena on weapon systems, personnel, and operations for mission planning. DCGS-A will utilize Air Force weather products available through reachback to the AF OWS and AFWA, including Open Geospatial Consortium (OGC) overlays, alphanumerics, metsat imagery and other products. The DCGS-A uses the latest Ozone/Widget and DCGS Integrated Backbone (DIB) technologies to distribute weather products to Mission Command and other users on the Enterprise.

***U.S. Army Test and Evaluation Command (ATEC).*** ATEC is responsible for providing operational meteorological support to USA RDT&E. Under responsibilities established in AR 115-10/ AFI 15-157 (IP), ATEC 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 Program Manager for Meteorological Support to USA RDT&E. Specialized services provided by the division include: (1) technical assistance to the ATEC operational meteorological teams/branches; (2) system administration support to the 4DWX system components and network connections at each ATEC test center; (3) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; and (4) 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

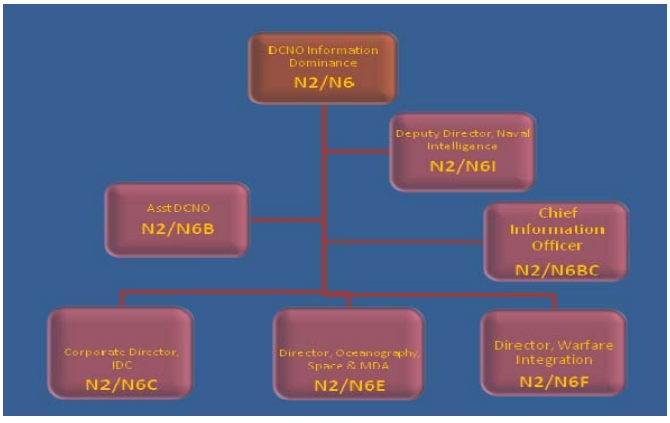
emergency operations. For further description of this support service, see "Other Specialized Services" in Section 2.

***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 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, Navy Space, Positioning, Navigation, and Timing (PNT). As the Oceanographer and Navigator of the Navy, he serves as the focal point for matters related to the Naval Oceanography enterprise (NOe) and related marine science fields. He represents the Commander Naval Meteorology and Oceanography Command (COMNAVMETOCCOM or CNMOC) and the Naval Oceanography Operations Command (NOOC), and his staff works closely with the U.S. Fleet Forces Command (USFF), Pacific Command (USPACOM), and the Office of Naval Research to ensure the proper resources are available to meet mission requirements. As the functional manager for Geospatial Information and Services (GI&S), he works within the National System for Geospatial-Intelligence (NSG) and liaises with the National Geospatial-Intelligence Agency (NGA), National Reconnaissance Office (NRO), and the Defense Threat Reduction Agency (DTRA). He acts as Naval Deputy to the NOAA Administrator and represents the Naval Oceanography Program in interagency and international forums, including the North Atlantic Treaty Organization (NATO) and the World Meteorological Organization (WMO). He ensures Navy and Marine Corps equities regarding remote sensing from space and collection through manned and unmanned vehicles to effectively meet warfighter needs for Battlespace Awareness and Knowledge Superiority.




Organization of the Deputy, Chief of Naval Operations (DCNO) for Information Dominance (OPNAV N2N6),showing placement of the Oceanographer and Navigator of the Navy, as the Director, Oceanography, Space, and Maritime Domain Awareness (MDA).

The Oceanographer also serves as the Navigator of the Navy and provides for the standardization of METOC, maritime geospatial information, astrometric and precise-time models, databases, and environmental predictive techniques. He coordinates NOe, 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. Information is no longer limited to an enabling role. Navy's Information Dominance initiative serves to consolidate and integrate information-related METOC activities and initiatives outlined in the Naval Oceanography - 2025 document, and Naval Oceanography's Battlespace on Demand (BonD) concept. This integrated approach can provide the Fleet with more timely dissemination of critical information about the physical environment and its impacts on platforms, sensors, weapons, and personnel. Bringing to bear a unique combination of scientific, and engineering excellence, warfighting experience, and engagement in a wide range of partnerships, Naval Meteorology and Oceanography support is integral to Navy, Marine Corps, and Joint Force capabilities to deter or win regional conflicts or major wars and conduct peacetime operations, including Humanitarian Assistance and Disaster Relief (HA/DR).

***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. The Oceanographer of the Navy serves as Director of TFCC and develops comprehensive approaches regarding the Arctic and global climate change to guide future Navy public, policy, and strategy discussions. TFCC recommends policy, strategy, and investments for the Navy regarding the Arctic and climate change that are consistent with existing national, joint, and naval guidance, including National Security Presidential Directive/ Homeland Security Presidential Directive (NSPD-66/HSPD-25), Joint Vision 2020, Sea Power 21, a Cooperative Strategy for 21st Century Seapower, Naval Operations Concept 21, The U.S. Navy's Vision for Information Dominance, Naval Oceanography 2025, and the Quadrennial Defense Review. Recent TFCC accomplishments include execution of the Navy's Arctic Roadmap and Climate Change Roadmap. Action items completed or underway include an Arctic Environmental Assessment, Arctic Capabilities-Based Assessment, Installation Vulnerability Assessment, and Identification of Arctic and Global Climate Change Research Needs. The Arctic and climate change Roadmaps provide all encompassing, chronological, science-based guidance for future Navy action from now through 2040.

***Naval Meteorology and Oceanography Command.*** The Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) is a third echelon command, reporting to USFF, and serves as the operational arm of the NOe. COMNAVMETOCCOM's assets are globally distributed at shore facilities in fleet concentration areas and larger production centers in the U.S. COMNAVMETOCCOM operates through the Naval Oceanography Operations Command (NAVOCEANOPSCOM) colocated at the Stennis Space Center (SSC) in Mississippi.

Naval METOC personnel (Navy and Marine Corps) are required to provide intelligence preparation of the operational environment (IPOE) 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.


The Naval Meteorology and Oceanography Command (COMNAVMETOCCOM), located at Stennis Space Center, MS, is the organization for operational Meteorology and Oceanography (METOC) reporting to U.S. Fleet Forces Command (USFF), headquarterd in Norfolk, VA.

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 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 is an echelon four command that coordinates and manages efforts among field activities under the Operational Oceanography enterprise 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 warfighting and enabling directorates for: Aviation Operations, Maritime Operations, Fleet Operations, Precise Time and Astronomy, Navigation, ISR (Intelligence, Surveillance, and Reconnaissance), Mine Warfare, Naval Special Warfare, and

Rear Admiral Jonathan White assumed duties as Oceanographer and Navigator of the Navy on 15 June 2012. Shown here (second from left), as Commander Naval Oceanography and Meteorology opening the Fleet Weather Center in Norfolk, VA. The Fleet METOC Watch floor combines and synchronizes maritime and aviation meteorological operations to allow for greater operational capability. (U.S. Navy photo by Mass Communication Specialist 3rd Class William Jamieson.

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 Director of Operational Oceanography (DOO).

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 Department of Defense, 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 NOe production center for meteorology. This center plays a significant role in the national capability for operational weather and ocean prediction by implementing, operating, maintaining, and improving Numerical Weather Production (NWP) systems, including 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.

Navy civilian Cecelia Spiering, a biologist at the Naval Oceanographic Office, takes an aliquot of suspended sediment for grain size analysis. Naval Oceanographic Office scientists analyze the physical, chemical, acoustic, and engineering properties of the ocean bottom sediment samples and apply the results to satisfy Navy requirements. (U.S. Navy photo by Public Affairs Specialist Shannon M. Breland).

***Naval Oceanographic Office.*** NAVOCEANO is the NOe'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 six ocean-class hydrographic survey vessels and data from both aviation assets and spacecraft .

***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

Indian Ocean (May 8, 2011) Sailors assigned to Destroyer Squadron One, disseminate satellite weather data from the meteorological center aboard the NIMITZ Class aircraft carrier USS Carl Vinson (CVN 70). CVN 70 and Carrier Air Wing Seventeen are underway in the Western Pacific Ocean. (U.S. Navy photo by Mass Communications Specialist 3rd Class Christopher K. Hwang).

***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. Naval oceanography enables the safety, speed, and operational effectiveness of the Fleet, by illuminating the risks and opportunities posed by present and future states of the natural environment.

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.

***Maritime Weather Operations.*** The Fleet Weather Center in Norfolk, VA supports operations for Commander Second Fleet (North Atlantic); Commander, Fourth Fleet (Caribbean Sea and South Atlantic); Commander, Sixth Fleet (Mediterranean Sea), and Arctic fleet operations.

The Fleet Weather Center in San Diego, CA supports operations for the Commander, Third Fleet (East Pacific); Commander, Fifth Fleet (Arabian Sea and Suez Canal); Commander, Seventh Fleet (West and Central Pacific) areas of responsibilities.

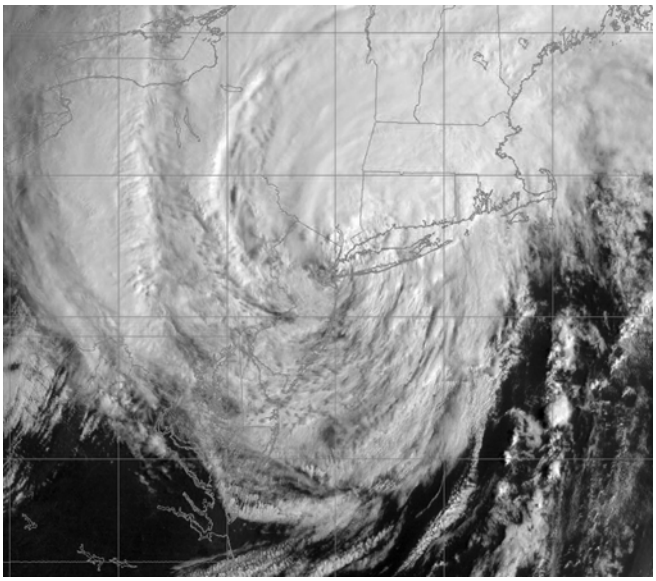
Navy meteorologists and forecasters provide Optimum Track Ship Routing (OTSR) and weather forecasts to support transoceanic voyages and coastal operations. OTSR services include:

- Hazardous ocean and weather advisories and divert recommendations to ship Commanding Officers and Masters at sea
- Sortie recommendations for potentially damaging weather conditions in port
- 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 enterprise (NOe).*** 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 NOe, 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.

***Littoral Battlespace Sensing (LBS).*** LBS is the Department of the Navy's IPOE 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 IPOE technology, a key component of the BonD framework, supporting Battlespace Awareness Joint Capability Area through 2025 and beyond.



ATLANTIC OCEAN (Aug. 28, 2011) A GOES-13 infrared satellite image provided by the U.S. Naval Research Laboratory, Monterey, Calif., showing the status of Hurricane Irene at approximately 6 a.m. EST Sunday, Aug. 28. Hurricane Irene made landfall near Cape Lookout, N.C. as a Category 1 hurricane and spun north along the Eastern seaboard. The storm made a second landfall near Coney Island, N.Y., and is affected the New England region later that day. (U.S. Navy photo/Released)

***FNMOC Numerical Weather Prediction Systems.*** FNMOC satisfies the military's requirement for an operational global Numerical Weather Prediction (NWP) capability. 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 treats 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.

East Pacific Ocean (July 21) - Aerographer's Mate 3rd Class Eric King, Norwalk, Ohio, and Seaman Olivia Mailander, Las Cruces, N.M., release a weather balloon to gather weather information aboard the amphibious assault ship USS Boxer (LHD 4). Boxer is currently participating in their Composite Training Unit Exercise (COMPTUEX) off the coast of Southern California. (U.S. Navy photo by Mass Communication Specialist 3rd Class Noel Danseco).

***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, EO, and FLIR system 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 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.

Many of FNMOC's products are distributed to users over the Web via the PC-based METCASTsystem, 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. 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. 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.

Twelve regional NCOMs are on line with 24 planned by 2014. 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. Global and regional NCOM products and data fields are shared with our NOAA partners.

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

***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 forecasters 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. FMF METOC activities are organized, trained, and equipped to provide

MARJAH, Afghanistan (June 24, 2010) Chief Equipment Operator Michelle Mathis guides vehicles, during a sandstorm, to build a Mabey-Johnson Bridge. The Naval Mobile Construction Battalion Five (NMCB-5) is in Afghanistan executing general engineering, infrastructure construction and project management.(U.S. Navy photo by Mass Communication Specialist 2nd Class Ace Rheaume)

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. Navy and USMC provide training for use of the Tactical Decision Aids (TDAs) at PDC and MAWTS-1 and in preparation for the deployment of SGOT's and MEU's. 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 Air Control Groups (MACG), and Marine Air Traffic Control Detachments. 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.

Forward Deployed Meteorological Mobile Facility System situated at Camp_Dywer_Afghanistan 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. (Photograph by Major James Glass).

## 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.

***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 MACG and its subordinate Marine Air Traffic Control Detachments. 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 Research Partnering Initiative

The Navy, Air Force/Air Force Weather (AFW), and NOAA/NWS partner in this tri-agency management organization. The National Unified Operational Prediction Capability (NUOPC) vision is a national numerical weather prediction (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 environmental 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 is scheduled to be doubled by the end of 2013 to one half degree, and doubled again to one quarter degree in the next several years as computing and communications capabilities grow to support this requirement. The partners continue to use and develop ensemble-based products such as the new Wave Watch 3 Ensemble, based on this multi-model system, that brings substantial skill improvements over any single model solution.

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 groundwork for the next generation environmental prediction system. More information is available at the NUOPC website at: weather.gov/nuopc

## 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.

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 National Center for Atmospheric Research (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.

In early 2012, AFWA put a capability called the Air Force Weather Ensemble Prediction Suite (AFWEPS) into operations. AFWEPS output, at both the mesoscale and global scale, provides 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 provides probabilistic algorithms for high-impact variables and quantify biases, allowing concise, focused products.

***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 Army systems and personnel at very high spatial and temporal resolution. Current R&D includes basic and applied research in atmospheric science to provide actionable environmental intelligence crucial to the success of current and future operations. The research program focuses on (1) measurements, modeling, and theoretical investigations and analysis of aerosols, acoustics, and optics to support advances in detection and identification within the battlefield environment; (2) research to measure, model, predict, and understand the dynamics of the boundary layer atmosphere for its effects on Army systems and operations; (3) research necessary to meet the Army's requirements for detailed atmospheric analyses and very short range predictions (nowcasts) over mission execution battlespace domains in complex terrain areas and within urban environments.

The applications and products developed from the division's 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. 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, and mobile weather technologies.

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 Weather Running Estimate – Nowcast (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. These weather impacts products and related new capabilities are being tailored for use on mobile handheld devices to provide soldier-specific and individualized weather impacts knowledge to personnel at the lowest echelons.

***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 (ABLE) 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 (LREAC™) system. It is also becoming operational for limited use in identifying very high resolution terrain effects on boundary layer wind flows in mountainous terrain.

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 complex terrain. These models support research on biologically inspired methods for micro autonomous systems to sense and react to the local turbulent atmosphere. Atmospheric dynamics and effects are measured and modeled for

emerging technologies in terahertz-band sensing and imaging, and atmospheric propagation for passive imaging, and active laser systems.

***Battlefield Environment Division, Atmospheric Sensing Branch*** The Atmospheric Sensing Branch addresses the development of technologies for improving characterization of soldier-scale atmospheric processes, atmospheric aerosols, electro-optical and acoustic propagation, and soldier battlefield awareness, survivability, and tactical decision-making. Its research objectives include improving techniques for rapidly characterizing potentially hazardous atmospheric aerosols; providing novel aerosol detection methods that are more rapid and less expensive to operate; enhancing situational awareness of improvised explosive devices (IED) and hostile fire through: physics-based acoustic source localization and classification for ground and airborne sensors, integrated hyperstereo imaging for displays, and polarimetric infrared (IR) imaging for aided and automatic target recognition; and improving environmental awareness through advances in electro-optic and acoustic remote sensing.

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. Additionally, branch efforts involve the fundamental understanding of the atmospheric turbulence effects on tactical and long-range laser beam propagation, as well as efforts to develop advanced techniques for mitigation and adaptive turbulence correction for directed energy systems.

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.

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

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, two-dimensional angular optical scattering techniques, and Raman will improve the understanding of aerosols in natural environment.

***ARL Army Research Office.*** The Army Research Office, Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamical and physical properties, processes, and constituents of the atmospheric boundary layer 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 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, 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 Corps of Engineers (COE) is responsible for reviewing emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The COE Engineer Research and Development Center (ERDC) develops TDAs 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 RDTE 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, tactical decision aids, 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 NCAR on enhancements to the ATEC 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 computers installed at each test center to execute the 4DWX models have been 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 has enabled easier and more consistent security upgrades and maintenance.

The DoD High Performance Computing Modernization Office provided the 4DWX program with a high-performance computer (HPC) that since 2007 has enabled operational mesoscale ensemble forecasts to support 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. With this HPC approaching the end of its life cycle, in 2012 DPG purchased a replacement system, which will be used for model evaluation studies until the original HPC is no longer operable.

System enhancements during FY 2012 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 additional types of data, continued development of both ensemble and analog probabilistic techniques, implementation of updated terrain and land surface data, and initial work on Large Eddy Simulation (LES) components for 4DWX. Initial installation of the AutoNowcaster thunderstorm prediction system at the Redstone Test Center (RTC) was completed. System enhancements during FY 2013 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 hybrid data assimilation; improved lightning potential prediction; development of range climatologies; continued development of LES capabilities; and initial development of an on-line automated real-time quality control for observations. 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) system administration support to the 4DWX system components and network connections at each ATEC test center; (3) atmospheric model verification and validation, including algorithm evaluation and the generation

of validation data sets; and (4) 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.

### U.S. Navy Supporting Research Programs and Projects

***Resource Allocation.*** The Chief of Naval Operations (CNO), through the Oceanographer of the Navy, sponsors operational Navy Meteorology and Oceanography (METOC) services and related research and development. In 2012, the Oceanographer of the Navy acquired responsibility for funding the Navy's meteorology and oceanography Operations and Maintenance (O&M,N) funding from the Deputy Chief of Naval Operations, Director for Material Readiness & Logistics, Fleet Readiness Division (OPNAV N43).

***Program Alignment.*** The Naval Oceanography Enterprise (NOe) 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 space weather conditions and space weather storms that can affect terrestrial systems, Earth's atmosphere, and the near-Earth space environment. Space weather services include monitoring and reporting of space weather storms and their effects on the Earth's atmosphere, ionosphere, and geomagnetic fields. Early warning of an approaching space weather storm, so that timely protective response is possible, is an important part of space weather services.

## OPERATIONAL PROGRAMS INCLUDING PRODUCTS AND SERVICES

### NOAA/National Weather Service

#### 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 conditions in the space environment that impact systems and technologies that are vulnerable to space weather. The SWPC provides real-time monitoring and forecasting of space weather events, conducts research in solar-terrestrial physics, and develops techniques for forecasting space weather storms. These services are provided to promote public safety and mitigate economic loss that could result from disruption of critical systems such as satellite operations, communications and navigation systems, and electric power distribution grids. The SWPC operates the national civilian Space Weather Forecast Office, coordinating with Air Force Weather Agency (AFWA) 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 services to customers on a 24 hour-per-day, seven day-per-week basis. SWPC forecasts and products include observations of solar, interplanetary, geospace, ionosphere, and thermosphere conditions that impact technologies at Earth. The SWPC also develops 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 including DOD, NASA, DHS, DOE, and FAA. The SWPC provides support to industries, public institutions, and private individuals including the electric power industry, the airline industry, the satellite industry, oil exploration, agriculture, and many users of HF communication and satellite navigation. 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.

### U.S. 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 FY2013 and beyond. In FY 2013, 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

The Federal Emergency Management Agency (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/National Weather Service

#### Space Weather Prediction Testbed

The SWPC operates the Space Weather Prediction Testbed (SWPT) to provide the operational Space Weather Forecast Office with new models, products, and forecast techniques. The SWPT performs applied research and evaluates scientific developments from other agencies to develop and identify new capabilities that could improve the prediction skills of the space weather forecasters. The SWPT validates and verifies new research results and works to transition research developments into operational products and services. Through these activities the SWPT 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.

SWPT 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 the SWPT include the following:

- Improvements in the one-to-four day forecasts of space weather storms by improving 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.
- Improving services to the electric power industry by evaluating and testing 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.
- Improving estimates of auroral impacts by the development and transition of an auroral forecast model that will provide estimates of where and how intense the aurora will be. These forecasts will be used in other space weather models as well as by the general public interested in observing aurora.
- Improving services to GPS/GNSS satellite navigation customers by the development of the Whole Atmosphere Model which extends 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.

### U.S. Geological Survey

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

The objective of the Heliophysics Division of National Aeronautics and Space Administration's (NASA) Science Mission Directorate (SMD) is 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 interplanetary space. In short, the focus is on our local star – the Sun – and how it supports our solar system and ultimately, life and society on Earth.

The three areas of concentration are theory development, data collection and analysis, and modeling of the resulting scientific understanding. To support this effort, the division operates a fleet of 17 missions involving 26 spacecraft. The region of space that must be covered is huge, extending from the Sun through the Earth's near-space environment and outward to the edges of the solar system.

Currently, four NASA research missions provide data that have become essential to our nation's space weather protection community. This is done by either direct broadcast from the satellite to a network of NASA and non-NASA receiving antennae, or by data that is processed in near real-time and made accessible via the internet. The Advanced Composition Explorer (ACE) spacecraft provides data on the condition of the solar wind upstream of the Earth's magnetic field. ACE is in extended mission status and its replacement has become a priority at NASA, at NOAA, and for the DOD. Other such missions are the Solar Dynamics Observatory (SDO), Solar and Heliophysics Observatory (SOHO), and the Solar Terrestrial Relations Observatory (STEREO). NASA deployed Radiation Belt Storm Probes (RBSP) in August 2012, which will provide near-real-term information on the Earth's radiation environment.

NASA also supports the development of models with its Research Program and the Living with a Star Science Program. With the Research Program's instrument development funding, NASA is developing the next generation of instruments that will be capable of observing extreme space weather conditions. NASA works to continually improve the understanding of space weather and enable improvements to space weather prediction models. Also, within the Research Program, as a quality assurance activity to validate solar and space physics research models and to prepare them for transition into operational activities, NASA operates a Community Coordinated Modeling Center (CCMC), an interagency collaborative activity involving the NSF, NOAA, and the DOD. The output of these models are 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 models within the broad range of national space weather activities. The intent of this effort is to transfer the tools and techniques of CCMC research into the operational arena—the ultimate objective of the National Space Weather Program.

### Department of Energy

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 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 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 National Science Foundation (NSF) supports the NSWP in pursuing the program's objective to perform the research and technology transfer needed to improve the specification and forecasts of space weather events that can cause disruption and failure of space-borne and ground-based technological systems and that can endanger human health. NSF supports space weather through dedicated programs as well as through basic space physics research programs. Space weather relevant research efforts include the development of large-scale space weather forecast models, construction and operation of advanced ground-based instruments and networks for the observation of space weather parameters, and the development and demonstration of innovative and creative small space weather satellites. NSF NSWP support in FY 2012 was estimated at $14 million and is expected to be around the same level in FY 2013.

### U.S. Air Force

#### Air Force Research Laboratory

The Air Force Research Laboratory (AFRL) supports Air Force Weather'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

### NOAA/National Weather Service

National Weather Service's (NWS) Marine and Coastal Weather Services is the lead for the Nation's marine and coastal weather services, encompassing a vast area from inter-coastal 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 up to 60 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, and numerical model guidance, NWS forecasters monitor weather conditions continuously over our responsible maritime areas. Routine forecast products and analyses, watches, warnings, and advisories are disseminated to describe maritime weather, sea ice and oceanographic conditions including tropical-storms and coastal storm hazards. Marine and coastal warning and forecast products describe wind, waves, visibility, icing, storm surge, coastal flooding, severe weather, high surf, and rip currents. Tropical-storm products describe track and intensity as well as associated coastal hazards such as storm surge, waves, and inland impacts.

The Marine and Coastal Services program collaborates with a wide range of partners within and outside of NOAA. The program relies on the Office of Operational Systems and NOAA's National Environmental Satellite, Data, and Information Services (NESDIS) for the collection of

marine and coastal observations and the delivery of marine and coastal products to users. It works with NESDIS, the U.S. Navy, and the U.S. Coast Guard (USCG) to provide ice warning and advisory services through the joint National Ice Center. It supports 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 collaborates with the DOD, FEMA, and USACE to provide tropical cyclone warning and forecast services; with the USCG, Navy, Air Force, and private entities to disseminate weather information to mariners; It supports NOAA's National Ocean Service (NOS) on the PORTS and TIDES programs; and through the World Meteorological Organization to coordinate maritime weather and ice safety services with national meteorological and hydrological services world-wide for consistent and seamless services for world oceans. It also collaborates with NOAA's Office of Response and Restoration, Department of Defense, USCG and Department of Homeland Security to support the emergency responses to maritime incidences such as hazardous material spills; maritime domain 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 were 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 were no 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 22 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). In FY 13, three new PORTS® are being planned in Jacksonville, FL, Matagorda Bay, TX and Charleston, SC. Of the three new PORTS® only Jacksonville will be adding new meteorological sensors.

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 twelve models at locations where physical measurements are not available. In FY12 the Northern Gulf of Mexico (including Galveston Bay and Mobile Bay)and the Columbia River models became operational. In FY13 a new model in San Francisco Bay is scheduled and the development of nested grid models in Mobile, Gulfport and Pascagoula to enhance the Northern Gulf of Mexico model. 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. In, FY12 new enhancements to render internal reports on station statistics and tighter quality control threshold values used to flag questionable data we added.

### U.S. 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.navcen.uscg.gov/?pageName=IIPHome. 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

#### Road Weather Management Program

The Federal Highway Administration (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 (primarily State Departments of Transportation), national laboratories, private firms, and universities across the transportation and meteorological communities. 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, which is housed in the Research and Innovative Technology Administration (RITA).

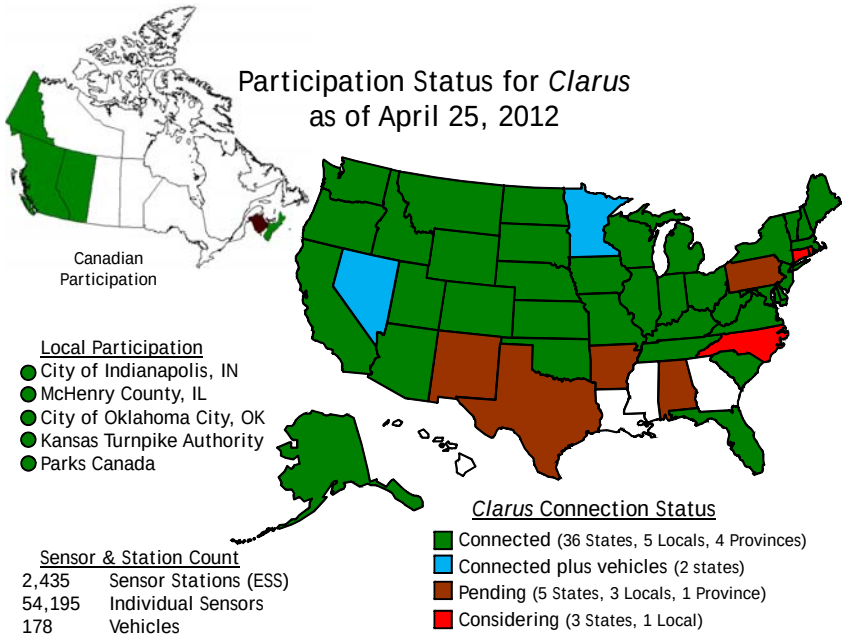
With funding authorized under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) at 5 million dollars per year, the goals of the RWMP are limited but span many areas to include: improving understanding of weather impacts on highway transportation systems, demonstrating a nation-wide system for observed road weather data, research new environmental data sources, enhancing road weather (e.g. pavement temperature) and traffic modeling with weather inputs, enhancing mechanisms for communicating road weather information to users, and developing decision support tools. For FY2011─ FY2013, 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 2013, these agencies will collaborate to develop and execute 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

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

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.

### 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. Major findings from the regional demonstrations are as follows:

- The value of road weather observations is clearly quantified
- Generally, the state DOTs participating in the evaluation have positive reactions to the tools. Some of the tools are closer to operational and deployment readiness than others
- Layering of information is critical. Users prefer to be able to choose the information being displayed
- Developing an effective end-user interface is critical to the success of the applications

In FY 2012, five universities and three private companies under FHWA contract completed 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 was accomplished by the same contractor that was awarded the National Mesonet Pilot and MoPED projects by the NWS. These cross-agency efforts have 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 into their operations. 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 of management strategies; test and evaluation of those strategies; 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 FY 2013, the RWMP will field test improvements to existing WRTM strategies to 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 was completed for initial implementation and deployment to begin on a limited basis in some US cities. Research is also being conducted 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, and is leading the Department's effort regarding the transportation Societal Benefit Areas of the National Earth Observations assessment. 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 surface transportation systems.

### Federal Railroad Administration

The Federal Railroad Administration (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.

## NOAA/National Ocean Service

### 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

The National Wildfire Coordinating Group (NWCG) is a collaborative group of partners with a shared vision and national responsibilities for wildland fire management. Each with individual missions, they focus on firefighter and public safety by improving coordination and integration through sharing talents, information, and resources. The NWCG provides leadership to the wildland fire community regarding training, standards, equipment, firefighting qualifications, and other wildland fire functions. The NWCG ensures that member agency efforts are consistent and coordinated while working collaboratively toward common goals. 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 USFS Research, and two entities with responsibility for wildfire management on non-Federal forest lands: the National Association of State Foresters and the Intertribal Timber Council. 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 Wildland Fire Executive Council (WFEC) for executives of offices directly responsible for wildland fire management.

The NWCG is organized into four branches. There are fourteen committees and numerous subgroups within the branches, representing the many business areas of wildland fire (such as aviation, equipment, fuels, qualifications). The NWCG committee most directly and frequently involved with capabilities for informing the wildland fire community about fire weather is the Fire Environment Committee (FENC) in the Equipment and Technology Branch. Permanent subcommittees currently chartered under the Fire Environment Committee are: . The Fire Weather Subcommittee (FWS) maintains the Interagency Wildland Fire Weather Station Standards and Guidelines, which addresses the network of permanently located Remote Automated Weather Stations (RAWS), portable stations used for incident response and prescribed fire, and manual fire weather stations. The Fire Environment Observation Unit under the FWS consists of the agency RAWS program managers who maintain the network of 2200 stations for their wildland fire agencies. The Fire Danger Subcommittee provides interagency direction to the Forest Service for the National Fire Danger Rating System (NFDRS) – a strategic planning tool - and its national processor, the Weather Information Management System (WIMS). RAWS and manual station observations are key weather inputs to the NFDRS in WIMS. The Fire Behavior Subcommittee provides interagency guidance for the use of fire weather observations for determining fire behavior predictions from a variety of tactical applications. These predictions include the work of the Fire Behavior Analyst working closely with the Incident Meteorologist (IMET) on fire incidents. National Predictive Services Subcommittee 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. In 2012, the FENC developed guidance released by the Executive Board on management of the RAWS network: http://www.nwcg.gov/pms/pubs/426/index.htm. The RAWS network is generally located in remote areas. RAWS observations fill a critical spatial gap in the initialization of the National Digital Forecast Database (NDFD).

### National Interagency Fire Center


Entrance to the NIFC in Boise, showing the logos of the participating Federal agencies and the National Association of State Foresters.

The National Interagency Fire Center (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.

The National Interagency Coordination Center (NICC), located at the NIFC, coordinates the national mobilization of resources for wildland fire and other incidents 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.

### NOAA/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. Finally, on a request basis, NWS forecasters issue spot forecasts for specific fire incidents or prescribed burn projects.

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.

The NWS has implemented regional digital weather files to complement currently-provided spot forecasts. The weather output enables Fire Behavior Analysts to directly input gridded weather data into 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 2012 improvements also include the creation of two fire weather specific gridded weather elements, and an improved spot forecast program with access to smoke trajectory modeling. . In addition NOAA and the USFS signed a fire weather research MOU that serves to coordinate applied fire weather research among the two agencies. Finally, the NWS renewed the Interagency Agreement for Meteorological Services with land management Agency Federal partners in September of 2012. The Agreement is valid through September 2017. 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 (USFS) 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 940 remote automated weather stations (RAWS) in a national network of over 2200 stations. The network provides real-time information which is key in the highly utilized Weather Information Management System (WIMS) used by fire agencies across the country. The data collected is crucial to supporting active wildfire decision-making including use in the Wildland Fire Decision Support System and associated fire modeling tools as well as for decision-making for prescribed fire operations. In FY 2011 and 2012, a cache of 15 combined smoke and meteorology monitoring devices has been established to support responses to smoke impacts from wildland fire and to aid in strategic decisions.

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 Forest Service RAWS Program 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.

The agency weather program works with the National Predictive Services Group at the NIFC to provide technical support and oversight to the 11 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.

The Wildland Fire Decision Support System (WFDSS) integrates emerging science and technology in support of risk-informed decision making. 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. Tools are being developed in FY 2012 that will aid in assessing multiple incidents for enhanced strategic decision making.

### U.S. Geological Survey

The U.S. Geological Survey (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.

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

***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

The National Aeronautics and Space Administration (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.

In 2012, NASA reviewed proposals focused on the application of Earth observations and models to wildland fire management activities. The Applied Sciences Program within NASA's Earth Science Division solicited feasibility studies and applied research related to wildland fires in support of management strategies and actions, business practices, and policy analysis and decisions. The solicitation also focused on multidisciplinary topics of health and air quality, ecological forecasting, water resources, disasters, and climate as topics related to wildfires. Of the 48 proposals received, NASA selected 17 projects for awards, addressing activities from pre-fire to post-fire stages. The projects will commence in late 2012. Projects will address fuel loads, fuel treatment planning, risk assessment, air quality, insect infestations, remediation, burned area rehabilitation, and other topics to support the use of Earth observations and models in land management approaches.

NASA collaborates with USFS, NIFC, and the California Department of Forestry and Fire Protection in the Wildfire Research and Applications Partnership (WRAP) project. The goal is 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. The WRAP project efforts in 2012 focused on transitioning the NASA Autonomous Modular Sensor (AMS) airborne imaging spectrometer, and associated sensor operations capabilities to operational use on the National Interagency Fire Center (NIFC), National Infrared Operations (NIROPS) aircraft. The AMS will be flown in FY 2013 as an additional sensor asset, supporting national assessment capabilities during wildfire season in the US. The sensor will augment capabilities of the wildfire management community, and allow the NIFC to maintain 24/7 imaging capabilities during peak fire seasons, when they are frequently over-subscribed in their support to emergency situations. Efforts focused on sensor adaptation to both a jet and turbo-prop aircraft, systems engineering, and operations training and test / evaluation flights will occur at the end of FY 2012 and early FY 2013. When operational on USFS NIFC aircraft, the sensor will be a shared resource asset, supporting wildfire observations for applications (intelligence support to incident managers), and to the wildfire scientific community (including NASA), with improved measurement capabilities of distinct fire properties that influence biological and atmospheric processes.

# 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

The National Aeronautics and Space Administration (NASA) provides operational weather support to spaceflight operations through the Human Exploration and Operations Mission Directorate (HEOMD).

#### Kennedy Space Center Weather Office

The HEOMD 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 and its successor manned spaceflight programs, 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). KSCWO also provides daily staff meteorological support to KSC and NASA programs operating from KSC or the Eastern Range.

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 criteria for lightning flight commit at commercial spaceports.

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In FY 2012, the KSCWO:

- Supported Space Shuttle Transition and Retirement (T&R).
- Supported the Tri-Program through infrastructure and requirements concept studies for the Space Launch System (SLS), Multipurpose Crew Vehicle (MPCV), Ground Systems Development and Operations (GSDO), and Experimental Flight Test 1 (EFT-1).
- Led the Weather Sub-Team of the joint NASA/Air Force Future State Definition study to define the architecture of the combined KSC/Eastern Range assets through 2025.
- 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.
- Began procurement of a replacement for the aging 50 MHz Doppler Radar Wind Profiler (DRWP) that supports all launches from KSC and the Eastern Range.
- Completed updating the KSC on-line Weather Archive website (http://trmm.ksc.nasa.gov/).
- Continued assisting the FAA with the development of Lightning Flight Commit Criteria for the commercial sector.

In FY 2013, the KSCWO will:

- 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 Tri-Program, and continue support for planning and design of the test flight programs.
- Support the transition and retirement activities of the Space Shuttle Program.
- Continue to work with the Eastern Range to define the requirements and infrastructure for weather support at KSC and CCAFS in the post-Shuttle era.
- Continue procurement of a replacement for the 50 MHz DRWP.

### Spaceflight Meteorology Group

The SMG is located at JSC. In FY 2012, the SMG:

- Operated with significantly reduced staff of 2 meteorologists in first half of FY12, and 1 meteorologist in second half of FY12.
- Provided consultation on the Orion/Multi Purpose Crew Vehicle program (MPCV), specifically Exploration Flight Test 1 (EFT-1) scheduled for April 2014.
- Supported two Orion parachute drop test events at Yuma Proving Ground, AZ with surface and upper wind forecasts.
- Supported NASA with enroute forecasts for recovery personnel flying from Houston to Kazakhstan and back to Houston—to retrieve U.S. astronauts landing on the Russian Soyuz spacecraft after flying on the International Space Station.
- Supported the JSC Morpheus Lander Project by providing forecasts and weather consultations for multiple Morpheus test firings at JSC in Houston.
- Provided support for multiple large outdoor events at JSC.
- Provided ongoing lightning and severe weather customized advisories for JSC management, weather sensitive operations, and employees.
- Prepared for AWIPS 2 transition scheduled for summer 2012.
- Participated in school outreach with schools across the U.S. via the JSC Educational Office Skype Studio.

In FY 2013, SMG will:

- Provide consultation on the Orion/Multi Purpose Crew Vehicle program (MPCV), specifically Exploration Flight Test 1 (EFT-1) scheduled for April 2014.
- Support Orion parachute drop test events at Yuma Proving Ground, AZ with surface and upper wind forecasts.
- Support NASA with enroute forecasts for recovery personnel flying from Houston to Kazakhstan and back to Houston—to retrieve U.S. astronauts landing on the Russian Soyuz spacecraft after flying on the International Space Station.
- Support the JSC Morpheus Lander Project by providing forecasts and weather consultations for multiple Morpheus test firings at JSC in Houston.
- Provide weather support to large outdoor events at JSC.
- Provide ongoing lightning, severe weather, and tropical storm/hurricane customized advisories for JSC management, weather sensitive operations, and employees.
- Support educational outreach events.

### The Space Radiation Analysis Group

The Space Radiation Analysis Group (SRAG) is located at JSC and is responsible for ensuring that the radiation exposure received by astronauts remains below established safety limits. SRAG is responsible for daily assessment of the Space Weather environment for human exploration, and works directly with flight control teams to assess in real-time mission impact of adverse Space Weather conditions. Some of the key Space Weather-related activities that SRAG is conducting in FY 2012 and FY 2013, include:

- Daily monitoring of the Space Weather environment and impact assessment for manned missions.

- Developing and maintaining protocols for radiation environment contingency response and analysis.
- Operating instruments both internal and external to manned spacecraft for radiation environment characterization, quantification and impact assessment.
- Developing collaborations for maintaining necessary space radiation measurements for instruments operating beyond planned lifetimes.
- Transitioning from research to operations of maturing Space Weather forecast models.

### 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.

In FY 2012:

- The NEB developed terrestrial environment specifications, and provided atmospheric data and models for vehicle design and operation for the Space Launch System (SLS) and Multi-Purpose Crewed Vehicle (MPCV) programs.

In FY 2013:

- The NEB will continue to develop and improve atmospheric wind and thermodynamic climatological data sets and models for vehicle design and operational safety margin analysis for the SLS and MPCV programs.
- The NEB will begin developing day-of-launch procedures relating to upper air wind and thermodynamic requirements for the SLS and MPCV 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. The 45th Weather Squadron directly supports the 45th Space Wing of Air Force Space Command at Patrick AFB, Florida, and Cape Canaveral Air Force Station, Florida. The 30th Operations Support Squadron Weather Flight supports the 30th Space Wing across the Western Range at Vandenberg AFB, California.

## U.S. Army Space and Missile Defense Command

### Support to the Ronald Reagan Ballistic Missile Defense Test Site (RTS)

Army Kwajalein Atoll, a subcommand of U.S. Army Space and Missile Defense Command (USASMDC), provides operational support to the RTS. The RTS meteorological services contractor provides support for range activities, including local and remote missile launches, missile weapons readiness testing, aviation and marine operations, and emergency operations.

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

A full suite of meteorological surface, upper air, satellite, radar, and lightning observing systems are available. Surface systems include an intra-atoll mesonet and 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) radiosondes, are located on Kwajalein and Roi-Namur. One portable GPS upper air system (403 MHz) is available to provide soundings at remote locations. A dual-polarized Doppler S-band weather radar provides weather surveillance from Kwajalein Island, and a Doppler C-band weather radar is available for operations at Wake Island. Both are volume-scanning radars that support prediction of lightning events. Two Polar-orbiting Operational Environmental Satellite (POES) satellite receivers (one mobile) and 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).

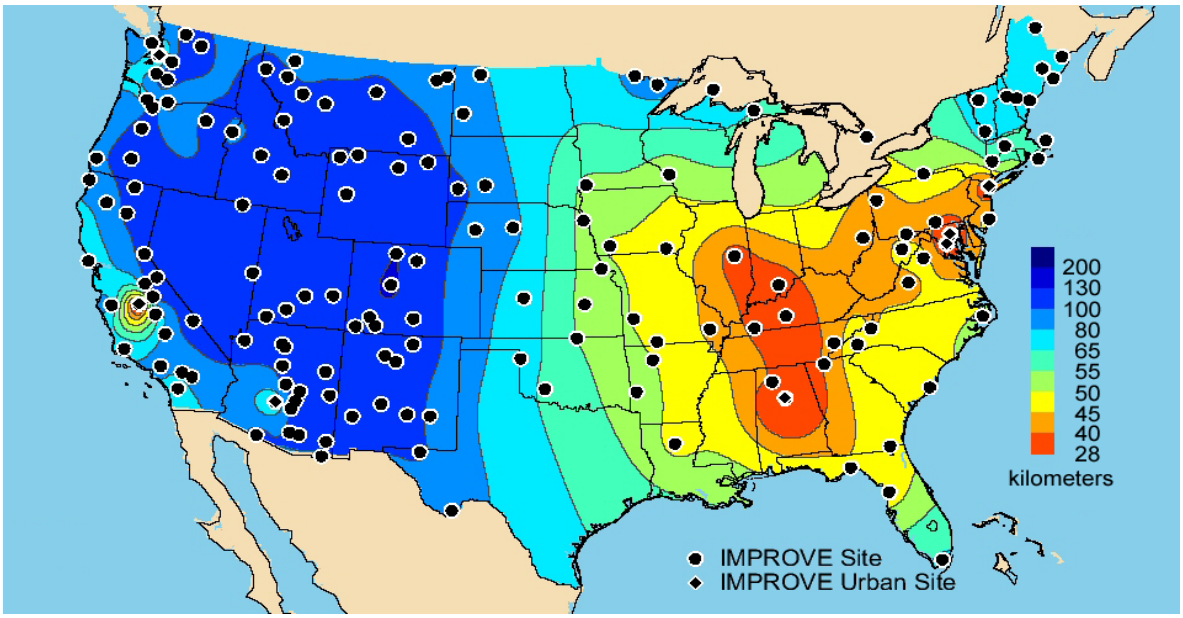
## National Park Service/Fish and Wildfire Service

### NPS Air Quality and Visibility Monitoring

The National Park Service (NPC) 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 Fish and Wildlife Service (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.




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.

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 above).

### Nuclear Regulatory Commission

#### Assessments and evaluations of radiological impacts.

At the present time, the Nuclear Regulatory Commission (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

### U.S. Army

#### U.S. Army Research Institute of Environmental Medicine

U.S. Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude and nutritional status on the health and performance of Warfighters and combat crews operating military systems.

Applied research in thermal physiology and biophysical modeling is directed towards improving Soldier performance and minimizing health risks in climatic extremes. The sensitivity of the Soldier to local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios. USARIEM is investigating methodologies needed to integrate real-time local environmental data and Warfighter physiological data with predictive model processes. The effective fusion of these two real-time data streams will enable near-term environmental strain and performance status predictions for Warfighters.

## National Park Service

### Air Quality Research

The National Park Service (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.

## National Aeronautics and Space Administration

### Kennedy Space Center Weather Office

The Kennedy Space Center Weather Office (KSCWO) is described in the section above on Operational Programs. In FY 2011, the Director of Research for the KSCWO was a co-investigator on a climate research proposal to a FY 2011 NASA/ROSES solicitation. The proposal was selected for award in FY 2012 and work on the research was begun. In FY 2013, the KSCWO will continue work on the project along with the Principal Investigator from Embry Riddle Aeronautical University and co-investigator from the University of Central Florida. The project is entitled “Vulnerability Analysis of the Environment, Facilities, and Personnel of the Kennedy Space Center (KSC) to Extreme Weather Events and Climate Anomalies Resulting from Global Climate Change.”

### Applied Meteorology Unit

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

In FY 2012, the AMU:

- Updated the Objective Lightning Probability Forecast Tool using the National Lightning Detection Network (NLDN) daily lightning flash count across central Florida to

determine if the data can be stratified by lightning sub-season instead of calendar month. Specifically, new elements included adding six more years of data from the 1989-2011 warm seasons of May-October to create a 23-year lightning climatology and adding October to the database. A correlation was not found between the NLDN flash count and lightning sub-seasons. Therefore, the existing tool was updated with the additional six years of data and included October as part of the warm season months.

- Developed Objective Lightning Probability Forecasts for commercial airports in East-Central Florida for which the National Weather Service in Melbourne has forecasting responsibility. Used NLDN lightning strike data from the 1994-2011 warm seasons of May-September. Calculated daily flow regimes and flow regime lightning occurrence probabilities for each airport. Stability parameters from the CCAFS sounding were used to calculate candidate predictors. After the data were stratified by month, logistic regression equations were developed and their performance was evaluated. Delivered the capability in an Excel-based graphical user interface (GUI).
- Developed a capability for the 30 WS at Vandenberg AFB (VAFB) to determine the frequency of occurrence of potential violations of user-driven launch weather upper-level wind constraints to improve the overall forecast and probability of violation on the day of launch. Used the 1994-2011 VAFB soundings to determine the probability of violation of specific user constraints for maximum wind speed and shear within specified altitudes in support of the Minuteman III ballistic missile operations. Delivered the capability as an Excel-based GUI.
- Developed a capability for the NASA Launch Services Program for 45 WS launch weather officers (LWOs) to rapidly assess Global Forecast System (GFS), North American Mesoscale (NAM) and Rapid Refresh (RAP) model forecasts of upper-level winds by calculating the differences between the model data and current upper-level wind speed and direction observations from the KSC 50 MHz Doppler Radar Wind Profiler and CCAFS Automated Meteorological Profiling System (AMPS) soundings during launch operations. Developed code in Excel to ingest and graphically display real-time model and observational data and delivered the capability as an Excel GUI to the LWOs.
- Investigated the feasibility of creating a dual-Doppler capability using the 45 Space Wing and NWS Melbourne Doppler radars. This would provide a three-dimensional display of the wind field and enhance the forecasters' ability to predict the onset of convection and severe weather. Conducted a literature review and consulted with experts to determine the requirements necessary to establish a dual-Doppler capability and investigated cost considerations and viable alternatives to implement the dual-Doppler capability.
- Evaluated configurations for a high-resolution model for the Eastern Range (ER) and Wallops Flight Facility (WFF) to better forecast a variety of unique weather phenomena in support of space launch activities. Ran test cases for the warm and cool seasons using several Weather Research and Forecasting (WRF) model domain configurations. Preliminary results comparing the WRF model forecasts against wind tower, accumulated precipitation, and sounding data show that Advanced Research WRF (ARW) outperforms the WRF Non-hydrostatic Mesoscale Model (NMM).
- Assessed the utility of using Global Positioning System (GPS) precipitable water (PW) and output from the AMU objective lightning probability tool to predict the probability of

lightning at a possible temporal resolution of every 30 minutes, the temporal resolution of the GPS PW. Conducted tests to determine the time period for the GPS PW change that produces the best probability forecast. If the output from the new analysis improves the lightning prediction capability, then the AMU will develop a GUI to display the probability of lightning.

- Supported launch operations for three Atlas V, one Delta IV and one Falcon 9.

In FY 2013:

- For FY 2013, the specific tasking for the AMU will be determined at the annual Tasking Meeting to be held during the 4th quarter of FY12.
- FY 2013 taskings are expected to be similar in kind to those for FY 2012 and previous years.
- For information about the AMU tasking process and previous years' taskings, consult the AMU website at http://science.ksc.nasa.gov/amu/.

## Environmental Protection Agency

### Air Quality Research

Meteorological support to the Environmental Protection Agency (EPA) 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 February 2012. 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. New versions of the CMAQ modeling system and associated documentation (Installation and Operations Manual, User Manual, Science Document, and tutorial) are publicly available. 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 on an operational basis and fine particulate matter forecast on an experimental basis. 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 hydrology and atmospheric models; coupling of meteorology and atmospheric chemistry calculations to account for the influence of radiatively active atmospheric pollutants on atmospheric dynamics and subsequent effects on air pollution; 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.

# 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 |

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|---|---|
| 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 |

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|---|---|
| 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 |

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|---|---|
| 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 |

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|---|---|
| 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 |

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|---|---|
| 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] |

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|---|---|
| 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 |

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|---|---|
| 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] |