The Federal Plan for Meteorological Services and Supporting Research

Fiscal Year 2016

OFCM

A Half-Century of Multi-Agency Collaboration

OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH

FCM-P1-2015
U.S. DEPARTMENT OF COMMERCE/National Oceanic and Atmospheric Administration

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The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 2016

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PREFACE

This edition of the *Federal Plan for Meteorological Services and Supporting Research* marks the beginning of a new era in Federal meteorological coordination and the Office of the Federal Coordinator for Meteorology (OFCM). As stated by Mr. Samuel P. Williamson in the preface to the document *The Federal Role in Meteorological Services and Supporting Research – A Half Century of Multi-Agency Collaboration:*

> *"…the federal meteorological enterprise is poised to continue delivering ever greater value in meeting the Nation's changing needs for meteorological and climatological services and products."*
>
> *"…I look forward to the next half-century of challenges for OFCM. With the nation's continued support, we will strive to surpass the remarkable record set during our first half-century."*

2015 has been a year of great change for many of the partners of the federal meteorological enterprise. Several organizations, including the OFCM, are undergoing substantial reorganization. As part of this transition, Mr. David McCarren accepted a temporary appointment from the CNMOC to serve as Acting Federal Coordinator for over eight months. During that time, we conducted a broad survey of the organizations participating in the Federal Coordinating Infrastructure to gather input to inform decisions regarding the future direction of OFCM. With strong leadership and support from the Undersecretary of Commerce for Oceans and Atmosphere, Dr. Kathryn Sullivan, the Federal Committee for Meteorological Services and Supporting Research (FMCSSR) met for the first time in over ten years. Interdepartmental Committee for Meteorological Services and Supporting Research (IMCSSR) later met to approve substantial changes to the Federal Coordinating Infrastructure. As a result, the ICMSSR deactivated all four Program Councils and assumed responsibility for all executive-level coordination within the Federal Coordinating Infrastructure. This action also reduced the number of subordinate Committees, Working Groups, and Joint Action Groups by 35%.

Amid all this change, the 15 agencies of the Federal Coordinating Infrastructure continue to work together toward common goals in a number of important areas.

The Committee for Operational Environmental Satellites is working to improve interagency communication and coordination of matters regarding the use of environmental satellites. In 2015 they documented broad Federal agency support and needs for international cooperation to cover environmental satellite data coverage of the Indian Ocean and continued night visible imagery from the NOAA polar orbiting satellites. In data-related work, the Satellite Telemetry Interagency Working Group (STIWG) has been reintegrated in the federal Coordinating infrastructure to heighten agency awareness of the Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS) and opportunities for data sharing and collaboration.

OFCM continues to play a critical role in supporting cooperation through the Committee for Operational Processing Centers and its subordinate working groups. Establishment of a new information security-compliant communications infrastructure has been a top priority.

We will continue to plan, organize, and host the Interdepartmental Hurricane Conference to share information and prepare for next year's hurricane season, including publishing the 2016 *National Hurricane Operations Plan*. The Working Group for Tropical Cyclone Research is working to complete a mid-course assessment of progress in achieving our strategic research plan for tropical cyclones.

We are also eager to see the proof of concept system under development for dual-polarization phased array radar and the possibility to move forward with a full-scale Advanced Technology Demonstrator for Multifunction Phased Array Radar (MPAR). MPAR represents a potential breakthrough in economy across a number of radar applications.

Remarkable change and progress has been made in the area of Space Weather planning and interagency coordination. The National Space Weather Program continues to support the annual Space Weather Enterprise Forum in Washington DC and the new National Space Weather Strategy and Action Plans to be published in fiscal year (FY) 2016.

This is also an exciting time for discovering, acquiring, and employing new data streams from satellites, unmanned aircraft systems, and networks of observing networks across the country—all of which will be addressed through our interagency coordinating groups in the coming year.

This edition of the *Federal Plan* provides additional information on these topics as well as much more information about activities across the agencies. It provides Congress and the Executive Branch with a review of agency programs and activities in FY 2015, a comprehensive account of proposed programs for FY 2016, and an outlook for future investment. The *Federal Plan*'s narratives, timelines, and schedules are current as of September 2015.

I extend my thanks to our agency partners and their staffs for their dedicated efforts to contribute to this important document.

Paul A. Roelle, Colonel, PhD, USAF
Federal Coordinator for Meteorological
Services and Supporting Research (Acting)

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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) 2015 and 2016. A narrative outlook for FY 2017 is also provided where possible. 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 2015 and are subject to later changes. The data for FY 2016 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 2016 is $75.1 million for operations and supporting research, a 0.1% increase from the FY 2015 funding level. The increase in funding is in the area of supporting research and costs, offsetting a decline in meteorological operations. USDA staffing levels dropped nearly 10%, from 111 full-time equivalent (FTE) employees (including 8 contractors) to 100 (including 6 contractors). USDA has requested $55.2 million for research and development programs, an increase of less than $300,000 (0.5%) from 2015. For the National Institute for Food and Agriculture (NIFA), funding for Weather and Climate from FY 2015 through FY 2016 President's Budget remains at about $33 million, with continuing support for existing AFRI multi-year (continuation) awards and other AFRI awards with a Weather and Climate component. A slight decrease is expected for the Agricultural Research Service (ARS), the USDA's principal in-house scientific research agency. ARS conducts research on how to cope with annual variations of weather on crop and animal production, ecosystem services, and the environmental and economic sustainability of agricultural enterprises. Funding is also decreased for the Forest Service (FS) in the area of Wildland Fire Weather. 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 2016 amount requested for meteorological operations is just under $20.0 million, down slightly (0.7%) from the $20.1 million funding level in FY 2015. 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 meteorological staff of the Office of the Chief Economist's World Agricultural Outlook Board (OCE/WAOB) routinely collects global weather data and agricultural information to assess the impact of growing season weather conditions on crops and livestock production prospects, keeping USDA commodity analysts, the Chief Economist, and the Secretary of Agriculture and top staff well informed of weather impacts on crops and livestock worldwide. The Risk Management Agency (RMA) provides administration and oversight of programs authorized under the Federal Crop Insurance Act. RMA's Strategic Data Acquisition and Analyses (SDAA) unit works with Oregon State University's Parameter-Elevation Regressions on Independent Slopes Model (PRISM) Climate Group to develop and utilize spatial climate data sets to detect potential waste, fraud and abuse in the Federal crop insurance program and to assist underwriting in developing crop suitability mapping.

DEPARTMENT OF COMMERCE/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Weather Service

The National Weather Service (NWS) funding request for the FY 2016 President's Budget totals $1.10 billion and 4,540 full-time equivalents (FTE). This is a 1.1% funding increase over the FY 2015 Enacted. The NWS (http://www.weather.gov/) provides weather, water, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the protection of life and property and the enhancement of the national economy 24 hours every day. NWS is the sole, official and authoritative U.S. voice for issuing warnings during life-threatening weather situations. In FY 2017, NWS will continue to develop the next generation probabilistic hazard information paradigm, and a fully integrated field structure delivering consistent products and services. NWS will continue to sustain and enhance infrastructure for observations, facilities, and information technology.

Significant requested increases and decreases in funding over the FY 2015 program include the following:

- ***Space Weather.*** NOAA requests an increase of $2.5 million for a total of $4.9 million to support Research to Operations (R2O) and operational activities for space weather research observation systems and numerical model development. This enables NOAA to effectively utilize existing solar observations while developing an expanded suite of space weather numerical models.
- ***National Mesonet.*** NOAA requests a decrease of $10.5 million for a total $5.5 million. The request restores National Mesonet Network funding to levels included in the FY 2015 President's Budget and maintains support for the national Mesonet program which was created in 2014. NOAA is using congressionally directed FY 2015 appropriations, to continue to ingest data from mesonets, which can identify small scale features at the surface, such as changes in wind speed/direction, temperature, and pressure, each of which can indicate rapidly deteriorating weather conditions not shown by other observations.

- ***Establishment of Regional Enterprise Application Development and Integration Teams.*** NOAA requests a decrease of $10.1 million for a total of $2.5 million to reflect the significant efficiencies that can be achieved by transition to a new information technology (IT) service delivery model for the National Weather Service (NWS) forecast offices. NWS will create regionalized IT collaboration teams enabling higher consistency of service delivery in support of NWS' mission.
- ***Weather Forecast Office Maintenance.*** NOAA requests an increase of $1.0 million for a total of $7.6 million to restore WFO Maintenance funding to recent historical funding levels.
- ***Enhance Water Predication Capability.*** NOAA requests an increase of $4.0 million for a total of $9.5 million to expand NWS' hydrologic forecast services to provide improved flood forecasts and inundation mapping. This will enable NWS to develop and test new centralized national hydrologic modeling and forecast capabilities at the National Water Center (NWC). Centralized water modeling will improve efficiency and consistency in the hydrologic forecast process, apply to all water conditions, and provide predictions on a high resolution grid.
- ***National Tsunami Hazard Mitigation Program Grants.*** NOAA requests a decrease of $6.0 million for a total of $8.7 million. This reduction eliminates NOAA's partner funding for education and awareness grant programs through the National Tsunami Hazard Mitigation Program (NTHMP). NOAA is not seeking to terminate NTHMP with this action. NOAA will continue to fund critical tsunami program components in order to ensure timely and accurate tsunami warnings, watches and advisories.
- ***Improving Mid-Range Operational Weather Outlooks.*** NOAA requests a total increase of $9.0 million for a total of $9.0 million to extend outlooks out through weeks three and four (mid-range). Initial actions will focus on gaining skill in weeks three and four, where none exists today by designing, developing, implementing and operating the "skillful" multi-model coupled earth system modeling system. Addressing this challenge will require a sustained scientific research and research-to-operations efforts. This initiative will ultimately allow NOAA to provide for 30 day operational weather and water outlooks and longer lead severe storm outlooks.
- ***Next Generation Weather Radar (NEXRAD) Service Life Extension Program (SLEP).*** NOAA requests a planned increase of $7.4 million for a total of $16.7 million and to continue implementation of a SLEP to sustain the aging NEXRAD infrastructure that underpins severe weather forecast and warning services for high-impact events critical for a Weather-Ready Nation. This is a multi-year effort that began in FY 2015 and is anticipated to be completed in 2022.
- ***Sustain Weather and Climate Supercomputing.*** NOAA requests an increase of $1.8 million and for a total of $44.2 million for the continued procurement and operations and maintenance (O&M) of NOAA's Weather and Climate Operational Supercomputing System (WCOSS).
- ***Advanced Weather Interactive Processing System II Extended.*** NOAA requests a decrease of $1.5 million for a total of $20.1 million for AWIPS Technology Infusion. NOAA proposes to slow development and implementation of new tools and capabilities aimed at achieving the NWS Future Forecast Office operations.
- ***Dissemination Infrastructure.*** NOAA requests an increase of $9.7 million for a total of $9.7 million to upgrade network capabilities to reduce single points of failure and increase website capacity to NWS Field Offices. This will provide NWS Field Offices with reliable communication networks and robust websites reducing risk to mission operations during severe weather events.
- ***Ground Readiness Project.*** NOAA requests an increase of $1.4 million and for a total of $19.6 million and to ensure NWS is prepared to utilize the substantial increase in environmental satellite, radar, and model data that will improve weather warnings and forecasts which will come once GOES-R becomes operational. In FY 2016, NWS will perform network enhancements at field

offices, test GOES-R operations, test new products, and continue to build-out NWS networks all in advance of the GOES-R launch and during and after the FY 2015/2016 WCOSS upgrade.

- ***Re-architected NWS Telecommunications Gateway.*** NWS requests a planned reduction of $10.1 million for a total of $10.8 million to reflect the planned completion in FY 2017 of a re-architected NWS Telecommunications Gateway (NWSTG) at the primary and backup site. The re-architected NWSTG capability will ensure modern, scalable, extensible and reliable dissemination and infrastructure services using current best practices.
- ***Weather Forecast Office (WFO) and River Forecast Center (RFC) Relocations.*** NOAA requests an increase of $4.7 million for a total of $8.7 million to continue investments that provide tenant improvements (TI) and support costs associated with WFO and RFC relocations as well as structural repairs due to unacceptable conditions at leased and owned facilities that could impact operations.
- ***National Reconditioning Center/National Logistics Supply Center Relocation.*** NOAA requests a decrease of $8.1 million for a total of $0 for the planned completion of the NRC/NLSC relocation in Kansas City, Missouri.

National Environmental Satellite, Data, and Information Services

The National Environmental Satellite, Data, and Information Services (NESDIS) funding request for the FY 2016 President's Budget totals $2.38 billion and 885 FTE. This is a 7.0% increase over the FY 2015 Enacted. Looking into FY 2017, NESDIS will support key initiatives committed to providing real-time operations and data services as well as working toward developing the next generation of satellites to continue meeting its primary mission essential functions without incurring gaps in coverage.

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.

As authorized in the Consolidated and Further Appropriations Act, 2015, NOAA restructured NESDIS Operations, Research, and Facilities (ORF) and Procurement, Acquisition, and Construction (PAC) account Programs, Projects, and Activities (PPA). The new budget structure strengthens both the satellite and data management sides of NESDIS and better coordinates systems engineering and common ground services.

Significant requested increases and decreases in funding over the FY 2015 program include the following:

- ***Satellite and Product Operations: Data Center Operations (DCO).*** NOAA requests an increase of $4.6 million for a total of $10.1 million to operate and maintain the Comprehensive Large Array-Data Stewardship System (CLASS). These funds will transition the CLASS system from a test and development environment to full operations. CLASS provides NOAA with required long-term safe archival storage capacity and provides the general public with access to the preserved climatological, oceanographic, and geophysical data. The FY 2016 request is necessary to provide the operations and maintenance (O&M) for the core capabilities of CLASS, including;

- Maintenance support for the operational software and hardware;
- Meeting all security requirements;
- Technical training to keep operators' skill levels current; and
- Data analytics, data compression, data translation, and reprocessing of archival data

- ***Commercial Remote Sensing Regulatory Affairs (CRSRA).*** NOAA requests an increase of $0.2 million for a total of $1.2 million to enforce and ensure compliance with terms of new satellite license agreements. The Nation requires a consistent and transparent regulatory process for licensing private remote sensing space systems in order to promote U.S. technological competitiveness and economic security, while ensuring satellite operation is consistent with our national security, intelligence, and foreign policy needs. The CRSRA program supports these requirements while furthering the Nation's homeland security and national security missions.
- ***Office of Space Commercialization (OSC).*** NOAA requests an increase of $0.4 million for a total of $1.0 million to improve coordination between government and industry on space-related issues and increase opportunities for commercial solutions for NOAA and other civil government data acquisition requirements. OSC, managed by NOAA for DOC, is responsible for developing space-related policies and the promotion of the capabilities of the U.S. commercial space industry with foreign countries.
- ***National Centers for Environmental Information (NCEI): Big Earth Data Initiative.*** NOAA requests an increase of $1.1 million for a total of $2.0 million to render NOAA's environmental data holdings more accessible and useful to other U.S. Agencies and the Nation. These funds will support the Big Earth Data Initiative (BEDI), further enabling easy, open, and transparent access to NOAA's weather, climate, oceanographic, and geophysical data and derived environmental information. These data and information directly contribute to the Nation's management of its environmental resources and support a broad range of environmental intelligence applications. Funding will directly contribute to modernizing search, discovery and access methods; the provision of descriptive information for all data and information products; and support for the services necessary to transform NOAA's data into machine readable information. Several other U.S. Agencies with substantial earth data holdings (e.g. National Aeronautics and Space Administration (NASA), Department of Interior (DOI), Department of Energy (DOE), United States Department of Agriculture (USDA), Department of Defense (DOD), and others) are also engaged in coordinated, parallel efforts under BEDI.
- ***GOES-R.*** NESDIS requests a decrease of $109.0 million for a total of $871.8 million to continue satellite engineering development, production, integration, and launch activities for the four-satellite GOES-R Series Program to deliver required operational capabilities through 2036. The reduction includes $94.0 million as the planned reduction in the GOES-R program. Additionally, the FY 2016 request is decreased by $15.0 million achieved by a one week reduction in carryover available to the GOES-R program from FY 2016 to FY 2017. The reduction to the amount of carryover remains within the bounds of the NASA best practices of 6-8 weeks and does not change the program's content or life cycle cost.
- ***Jason-3.*** NOAA requests a planned decrease of $15.7 million for a total of $7.5 million to continue post launch operations of the Jason-3 satellite in partnership with European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and Centre National d`Etudes Spatiales (CNES), NOAA's European and French partners. NOAA will support routine post-launch operations of the Jason-3 satellite to include ingestion, processing and distribution of the data, and providing essential engineering services to sustain operations in the event of space or ground based

anomalies. Within this budget, NOAA will also complete the evaluation of the Jason-3 satellite and instrument performance during the calibration and validation of all satellite data and will support continued Jason-3 satellite operations per our interagency commitment with EUMETSAT and CNES.

- ***Joint Polar Satellite System (JPSS).*** NOAA requests a decrease of $107.3 million for a total of $809.0 million for the JPSS. These funds will operate and sustain the Suomi National Polar Partnership satellite (S-NPP) and continue development of the instruments, ground system, and spacecraft for JPSS-1 and JPSS-2. The reduction includes a planned reduction of $82.3 million to the established budget profile. Additionally, the FY 2016 request is decreased by $25.0 million achieved by a one week reduction in the carryover available to the JPSS program from FY 2016 into FY 2017. The reduction to carryover remains within the bounds of the NASA best practices of 6-8 weeks and does not change the program's content and life cycle costs.
- ***Polar Follow On (PFO).*** NOAA requests an increase of $380.0 million for a total of $380.0 million to initiate the PFO. NOAA is focused on achieving polar weather constellation robustness as early as FY 2023. The request funds the following actions to ensure continuity of NOAA's polar weather observations;
    - Initiates development to support launch readiness dates of Q2 FY 2024 for JPSS-3 and Q3 FY 2026 for the JPSS-4 missions.
    - Provides the option for a JPSS-3 contingency mission with critical sounders Advanced Technology Microwave Sounder (ATMS) and Cross-track Infrared Sounder (CrIS) only.
    - Invests in development of an advanced technology Earth Observing Nanosatellite-Microwave (EON-MW).
- ***Solar Irradiance, Data and Rescue (SIDAR): User Services Accommodation.*** NOAA requests a decrease of $6.8 million for a total of $0.5 million to plan for the accommodation of the Argos Advanced Data Collection System (A-DCS) and Search and Rescue Satellite Aided Tracking (SARSAT) instruments. SARSAT provides satellite search and rescue services, and A-DCS provides environmental data collection and relay. This request will allow NOAA to plan the accommodation for A-DCS and SARSAT for launch in FY 2019. NOAA will work with the Office of Management and Budget (OMB), the Office of Science and technology Policy (OSTP) and National Aeronautics and Space Administration (NASA) to develop a plan for the accommodation of these instruments. The Solar Irradiance measurements initially conceived as a part of NOAA's SIDAR program have been transitioned to NASA. Additionally, the Total Solar Irradiance Spectometer Instrument (TSIS) developed by NOAA will transition to NASA beginning in FY 2016. NOAA will continue to operate the Total Solar Irradiance Calibration Transfer Experiment (TCTE) instrument to provide the bridge between the Solar Radiation and Climate Experiment (SORCE) and TCTE. In FY 2016 and beyond, the SIDAR program will consist of A-DCS and SARSAT.
- ***Deep Space Climate Observatory (DSCOVR).*** NOAA requests a planned decrease of $17.9 million for a total of $3.2 million to support routine maintenance and operations of the refurbished DSCOVR satellite. NOAA will continue to support routine post-launch maintenance and operations for the DSCOVR mission. The funds will be used for sustaining engineering support for the Mission Operations Center (MOC) located at the NOAA Satellite Operations Facility (NSOF) in Suitland, MD. NOAA will provide mission operations, ground systems maintenance, and data processing and archiving. Additionally, NOAA will also provide on-orbit support and enhancements to the ground system. DSCOVR carries two earth remote sensing instruments

provided by NASA; the Earth Polychromatic Camera (EPIC) that will take continuous full disk images of Earth and the NIST Advanced Radiometer (NISTAR) that will take continuous full disk measurements of the earth's radiation balance.

- ***Space Weather Follow On.*** NOAA requests an increase of $2.5 million for a total of $2.5 million to analyze options from the Analysis of Alternatives (AoA) for critical space weather observations and to initiate development of the Space Weather Follow On mission. This entails developing preliminary versions of Level 1 Requirements, Concept of Operations, and program schedule for solar wind data and coronal mass ejection (CME) imagery for the program's key decision point review, Key Decision Point-A. The Space Weather Follow On program will be configured in consultation with NASA, interagency and international partners and consistent with the goals outlined in the National Space Weather Strategy that is being developed by Space Weather Operations Research and Mitigation Task Force.
- ***COSMIC-2/Global Navigation Satellite System Radio Occultation (GNSS RO): GNSS RO Ground System***. NOAA requests an increase of $3.3 million for a total of $10.1 million for ground reception and processing of GNSS RO satellite data from GNSS RO satellites. NOAA will use these funds to complete all IT security testing and verification in preparation of the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC-2) launches. There are two COSMIC-2 launches planned for FY 2016 and FY 2019, respectively. The first launch of six satellites is planned for an equatorial low earth orbit (24 degree inclination) and the second is planned to a higher inclination low earth orbit (72 degree inclination). The two different orbits are necessary in order to meet the NOAA signed Level 1 Requirement Document for GNSS RO data, with the main requirements being 45 minute average data latency and over 8,000 soundings for the system per day. The two launches ensure orbital distribution of low earth orbit satellites to provide the appropriate RO soundings.
- ***COSMIC-2/GNSS RO: COSMIC-2 (RO Sensors).*** NOAA requests an increase of $9.9 million for a total of $9.9 million for the procurement of the second set of six RO sensors to be launched in FY 2019 for the COSMIC-2 constellation. The COSMIC-2 constellation will consist of 12 total RO sensors. The first launch of six satellites in FY 2016, planned for an equatorial low earth orbit (24 degree inclination), is currently in production. The United States Air Force (USAF) is purchasing the first set of RO sensors to be flown on spacecraft procured and operated by Taiwan. The launch of the second set of six satellites is planned for FY 2019 to an inclination low earth orbit (72 degree inclination). Additionally, the acquisition and launch of the second set of six COSMIC-2 sensors will help to mitigate the impacts of a potential gap in polar satellite data on NWS forecasts, products and services.
- ***Satellite Ground Services (SGS).*** NOAA requests an increase of $2.7 million for a total of $58.5 million to continue the planning and transition of the independent ground services into a unified set of common ground services for NOAA's environmental satellite systems. This funding request will sustain SGS program activities implemented within the FY 2015 Congressional approval of the NOAA reorganization to leverage existing systems to provide new products and services and plan a future set of common ground services for NOAA's satellites. The funding request is needed to accelerate prototyping of software elements that can be used by multiple applications and to evaluate hardware options for technology refresh action. These activities are a critical step toward setting the foundation for an enterprise ground system that will ultimately generate cost savings and interface efficiencies across NOAA.
- ***System Architecture and Advanced Planning (SAAP).*** NOAA requests an increase of $1.6 million for a total of $4.9 million to establish and lead the system engineering processes necessary

to meet NESDIS' mission assurance needs. The funding increase is needed to provide adequate end-to-end validation of the GOES-R and JPSS-1 mission requirements to ensure the NESDIS' systems and products meet the operational needs identified by the user community. Fulfilling enterprise-level end-to-end validation has been a key focus of the NESDIS System Review Boards for NOAA's satellite missions, including GOES-R and JPSS. Funding this activity in FY 2016 is critical for GOES-R to complete development activities and to certify end-to-end validation of the GOES-R products and ground system prior to launch. Remaining funding will be used to support planning for the full development of next generation satellite and ground architectures. NESDIS architecture planning is integral to the long-term continuity of satellite products used for environmental monitoring and prediction at an affordable cost.

- ***Projects, Planning and Analysis (PPA).*** NOAA requests an increase of $5.3 million for a total of $30.5 million to prepare three critical NOAA instruments for launch on the European satellite called MetOp-C. PPA is responsible for the project management and integration lead for data exploitation of NOAA's satellites while providing on-orbit anomaly support and sustainment for existing operational systems. This funding request will allow NOAA to recalibrate the Space Environment Monitor (SEM) instrument on schedule to be shipped to Europe for satellite Dynamics and Electro-Magnetic Compatibility Testing. Without this funding request, NOAA will be unable to meet schedule obligation to ensure SEM's accommodation for launch on MetOp-C in Q1 FY 2019.
- ***Satellite Command and Data Acquisition (CDA) Facility.*** NOAA requests an increase of $0.01 million for a total of $2.2 million. The Satellite CDA Facilities Program ensures that power and cooling infrastructure is available 99.99 percent of the year, supporting the continuous collection, processing, and distribution of environmental data for the issuance of life saving NWS watches and short-term warnings to the public. This program supports the operation of critical infrastructure at the Wallops, VA, and Fairbanks, AK, Command and Data Acquisitions (CDA) stations, the NOAA Satellite Operations Facility (NSOF) in Suitland, MD, and the NESDIS Consolidated Backup (CBU) in Fairmont, WV. The NSOF and the CDA facilities have been determined to house National Critical Infrastructure elements by Presidential Decision Directive.

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 2016 President's Budget totals $167.8 million, 416 FTE. This is an 11.3% increase over the FY 2015 Enacted. Looking into FY 2017, OAR will continue to provide the Nation with critical environmental information to support informed decision-making and promote healthy, productive, and resilient ecosystems, communities, and economies. OAR will continue research focused on improving our understanding and forecasting capabilities for atmospheric events that endanger lives and property and research focused on establishing a greater understanding of, and ability to predict, climate variability and change, and to enhance society's ability to plan and respond. OAR will also improve current NOAA operational products and services by conducting innovative research for the development of the next generation of products and services.

- ***Climate Labs and Cooperative Institutes.*** NOAA requests a net increase of $ 10.5 million for a total of $70.5 million to support research activities that will help to gain a comprehensive understanding of the physical, chemical, and dynamical processes that shape our climate. NOAA will maintain and enhance NOAA's six Atmospheric Baseline Observatories (ABO) in order to deliver policy-relevant data and information on greenhouse gas emissions and other critical

atmospheric data. NOAA will improve support of the U.S. Global Change Research Program's (USGCRP) priority research areas, providing focused drought impacts research and applications development to underserved regions of the country. Finally NOAA will build upon its North American Carbon Observation and Analysis System (COAS) to establish a more robust network of sensors and carbon cycle modeling efforts to improve our understanding of the carbon cycle and the effect on the earth. OAR's Laboratories and Cooperative Institutes are central to the effort of the climate research community to improve that understanding, to test our understanding through the development of state-of-the-art Earth System Models, and then to use those models to predict the future state of the climate. Observations of the Earth system and their analysis underpin the efforts that form the scientific basis for Climate Research.

- ***Weather and Air Chemistry Research (W&ACR).*** This sub-activity includes Laboratories and Cooperative Institutes (CIs) and Weather and Air Chemistry Research Programs. NOAA requests a net increase of $6.5 million for a total of $97.3 million. Increases would go to research and development on improving the detection and understanding of severe weather with a new airborne phased array radar, accelerating operational implementation of forecasting capabilities which will improve the accuracy of warnings, extend lead times, and enhance decision support services for high impact weather, and improving accuracy of weather outlooks out to three to four weeks (i.e., in the "mid-range"). 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

National Ocean Service

The National Ocean Service (NOS) request for funding related to meteorological supporting research in the FY 2016 President's Budget totals $32 million with 117 FTE. This is a 2.2% increase over the FY 2015 Enacted. These funds allow for expanded operation of the National Water Level Observation Network (NWLON), and continued operation of the Physical Oceanographic Real-Time System (PORTS®) program, the data quality control program known as the Continuous Operational Real-time Monitoring System (CORMS), and 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 include subsets of operational water level stations with meteorological sensors installed for various partners and users, including the NWS. This is level funding with the FY 2015 Enacted. Looking into FY 2017, NOS will continue to provide meteorological observations which are critical to navigation activities and the safety of life and property.

Though traditionally an oceanographic observing system, NWLON/PORTS® technology allows multiple other sensors to be added, including meteorological sensors such as wind speed/direction/gusts, air temperature, relative humidity and barometric pressure. Additionally, NOS has eight PORTS® stations with operational visibility sensors, in Mobile Bay, AL, San Francisco Bay, CA and Jacksonville, FL. Several more are being added on Narragansett Bay and on the northern Chesapeake Bay. These meteorological observations provide important data for improving and verifying marine weather forecasts and warnings. NOS has upgraded and enhanced the majority of its NWLON stations with new meteorological sensors. This increase in meteorological observations has led to a 10% increase in the probability of detection of marine weather events and a ten minute

increase in lead times for marine warnings, according to actual verification data for special marine warnings (WFO Sterling).

Navigation data users require a complete picture of their operating environment, which includes local meteorological data, to make safe and cost-effective decisions. Leveraging existing observing infrastructure is a cost-effective alternative to establishing new platforms to collect these data. The additional meteorological data improves the accuracy of NWS forecasts for storm surge, marine wind speed, and marine wave heights, used by both marine navigation and coastal communities when extreme weather events occur. The real-time data can be used by emergency responders to make sound decisions based upon the most up to date and accurate information. For example, when coastal areas are flooding, emergency responders must know which evacuation routes are still viable and other related information that most accurately reflects the current state of the physical environment.

Office of Marine and Aviation Operations

The FY 2016 President's Budget requests $32.3 million and 121 FTE for the Office of Marine and Aviation Operations (OMAO) Aircraft Operations. This is a 2.2% increase over the FY 2015 Enacted. OMAO supports meteorological operations and research activities by collection of related data from aircraft. The fleet of aircraft support NOAA's mission of science, service, and stewardship. The aircraft operate throughout the United States and around the world; over open oceans, mountains, coastal wetlands, and the Arctic. OMAO provides capable, mission-ready aircraft and professional crews to study global climate change and air quality, assess marine mammal populations, survey coastal erosion, investigate oil spills, conduct coastal mapping, survey snowpack levels for flood prediction, and improve hurricane prediction models. AOC flight crews operate in some of the world's most demanding flight regimes including flying into the eye of a hurricane. Looking into FY 2017, OMAO will continue to support meteorological observations through its Aircraft Operations PPA.

DEPARTMENT OF DEFENSE

U.S. Air Force

U.S. Air Force (USAF) resources for meteorological support fall into two primary categories: general operations (includes operations, maintenance, and procurement) and research. The total Air Force weather operations and research funding request for FY 2016 is $141.2 million, an 8.2% increase from FY 2015, 2894 active duty military, 380 civilian, and 63 contractor personnel authorizations, a 3.4% decrease in overall personnel from FY 2015. There are no significant changes planned for FY 2017.

Operations

The operations support portion of the USAF weather FY 2016 budget request is $111.2 million and funds day-to-day environmental support to the Department of Defense (DoD), the Active Components of the Air Force and Army, nine unified commands, and other agencies as directed by the Chief of Staff of the Air Force. The USAF employs over 3,300 military and civilian personnel to conduct these activities at more than 184 locations worldwide. Additional personnel specializing in communications, computer, information technology, program management, program analysis, administrative, and logistics specialists support the weather mission in the Air Force. These resources are dedicated to providing dedicated, tailored weather support to US Air Force/US Army forces and platforms performing contingency and non-contingency operations around the globe. In addition, in FY16, the

Air Force will enhance its partnership with coalition nations by integrating the Global Air Land Weather Exploitation Model (GALWEM) into daily operations. This effort will provide a global numerical weather modeling capability that can be tailored to provide weather information supporting US and coalition air and land operations throughout the globe.

Supporting Research

The total Air Force budget request for meteorological-related research during FY 2016 is $29.9 million. As part of the Air Force Strategic Weather Modernization Plan, the USAF continues investing in modernized environmental prediction and commercial-off-the-shelf technologies that enhance automation and save resources. In support of Program Action Directive (PAD) 14-03, the Air Force transferred its meteorological-related research funding to Air Force Material Command and Air Force Space Command. PAD 14-03 also transferred the authority to prioritize the funds to Air Combat Command. The USAF plans to invest in the following efforts in FY 2016 and beyond:

- ***Weather Data Analysis (WDA).*** WDA provides a net-centric infrastructure that assimilates worldwide sources of atmospheric and space weather data and produces decision-quality information for warfighters across multiple security enclaves. This information is provided through both machine-to-machine and machine-to-human capabilities. In FY16, RDT&E activities will enhance the capability to ingest, process, store, access, and disseminate meteorological data via upgrades to the web services architecture to expand the Open Geospatial Consortium services and upgrade the large-scale data processing to accommodate new environmental satellite and numerical weather modeling data.
- ***Numerical Weather Modeling (NWM).*** NWM includes numerical weather prediction (NWP) models; cloud analysis and forecasting models; land surface characterization models; aerosol, atmospheric constituent, and point analysis models/applications; and both global and mesoscale ensembles. In FY16, RDT&E funds will be executed to implement GALWEM 12 km resolution products and integrate UK Meteorological Office (UKMO) ensemble, 4-dimensional Variational (4D-Var) data assimilation techniques, and convective scale applications. Additional funds will be used to operationalize improved cloud forecasting techniques and enhance aerosol modeling algorithms.
- ***Space Weather Analysis and Forecast System (SWAFS).*** SWAFS is the primary operational DoD source for space weather data, models, and products. SWAFS ingest and databases ground- and space-based space weather data and employs models and applications to create and disseminate specified space weather analysis, warning, and forecast products for weather and space operations personnel. In FY16, SWAFS will continue with the Net-Centric data transition as well as Ionsopheric Scintillation and Total Electron Count (TEC) Observatory (ISTO) integration. Funds will also be spent to operationalize the latest Global Assimilation of Ionospheric Measurements (GAIM) – Full Physics (FP) model capabilities to improve specification and forecasts of the ionosphere.
- ***Weather Services – Live, Virtual, Constructive (WS-LVC).*** WS-LVC provides Air and Space Natural Environment data for DoD Modeling and Simulation (M&S) applications, and integrates with US Air Force and US Army Live, Virtual, Constructive operational training systems to deliver a correlated and realistic natural environment with tailorable scenarios for specific warfighter effects. In FY16, RDT&E funds will be used to continue incremental development of air and space natural environment data and associated effects for use in tailorable scenarios within warfighter

models and simulations. This program was previously called Environmental Data Cube Support System (EDCSS).

The goals of these efforts are to provide accurate, relevant, and timely meteorological intelligence to operators and warfighters at all levels of operations, within their decision cycle(s), and in a manner that facilitates exploitation of the current and forecasted environmental conditions.

U.S. Army

The U.S. Army (USA) estimates a $26.7 million request for FY 2016 including 47 Civilian, and 22 Contractor personnel authorizations. This request consists of $14.4 million for operational support and $12.3 million for research and development, an overall decrease of 2.8% from FY 2015.

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. Forces Command, U.S. Army Europe, Eighth U.S. Army, U.S. Army Pacific, and U.S. Army South have Air Force Active Component, Reserve Component, civilian, or contract 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 full time meteorologist at TRADOC's Army Weather Proponent Office (AWPO) to manage weather capabilities development efforts. The two AF specialists also oversee USAICoE's combined Army/Air Force Battlefield Weather Course (4 weeks of instruction) held at Ft. Huachuca, AZ. TRADOC employs one meteorologist to oversee the Distributed Common Ground System-Army (DCGS-A) weather initiatives and objectives. DCGS-A is the Army's intelligence, surveillance, and reconnaissance enterprise for the analysis and processing, exploitation, and dissemination of information and intelligence data, across all echelons. DCGS-A also leverages Air Force Weather Capabilities, integrates tailored weather information and products provided by the Air Force and disseminates to Army mission command.

The Army 2015 procurement funding is applied to the technical refresh of the fielded ruggedized laptops for Profiler Virtual Module (PVM) and the training and fielding of PVM version 1.0.0.4 to the Army. The Army 2015/2016 RDT&E funds are required for the development of PVM version 1.0.1 integrating changes to the weather model to use the Unified Model (UM) data and Gridded Binary v2 (GRIB2). FY2016 procurement funding covers the training and fielding of PVM 1.0.1.0 and the completion of the ruggedized laptop fielding. The Army 2016 RDT&E funds begin development of PVM v2 migrating to a service on the Command Post Computing Environment (CPCE) architecture within the Common Operating Environment (COE).

In its civil operational activities, the Corps of Engineers (COE) uses a network of approximately 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. The COE funds or partially funds nearly half of all the gages it uses.

The COE 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. 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. Army Europe and U.S. Army Pacific maintain a small budget to fund Army-owned automated weather-sensing systems within their respective areas of responsibility.

Estimated budgets for meteorological research remain relatively unchanged from FY 2015 to FY 2016. Within the Army Materiel Command/Research Development & Engineering Command will continue research and development efforts in basic and applied atmospheric science. The Army Test and Evaluation Command (ATEC) meteorology program budget will continue to provide meteorological support to Army RDT&E ranges in FY 2015 and 2016. This budget will increase in FY 2016 to support a single year life cycle replacement of large computer systems to operate the Four-Dimensional Weather (4DWX) weather modeling system. In FY 2017, this budget will return to a level required to support baseline meteorological operations and support.

U.S. Navy

The U.S. Navy FY 2016 budget request for meteorological programs is $ 126.9 million, made up of $ 105.1 million for operations and $ 21.7 million to support enabling research. These numbers reflect a combined decrease from FY 2015 of 2.7%. Requested manpower authorizations include 415 Navy active duty, 370 Marine Corps active duty, 75 civilian personnel authorizations, and 18 contractors.

Naval Oceanography Program (NOP)

The Chief of Naval Operations, through the Oceanographer of the Navy, sponsors operational Navy Meteorology and Oceanography (METOC) services and related research and development. In August 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). Since that date, the Oceanographer of the Navy has served as the Director of Oceanography, Space, and Maritime Domain Awareness for the Navy, within the Information Dominance Corps. In August 2014, the Chief of Naval Operations established the Information Dominance Type Command. Resource Sponsor (OPNAV), Operational Commander (CNMOC), and TYCOM (IDFOR) all work

together to field capabilities. One provides the money, the other the requirements, and the TYCOM man, trains, and equips all Navy Weather activities.

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. 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 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. Numerical Weather Prediction (NWP) comprising both model development and forecast skill are being pursued through the Earth System Prediction Capability (ESPC), discussed 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 global weather prediction 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 delivered through its SCN, two T-AGOR research vessels, to be operated by civilian research institutions in coordination with the University National Oceanographic Laboratory System (UNOLS). An Auxillary General Survey vessel (T-AGS) USNS MAURY will be delivered in FY 15.

Navy's Earth System Prediction Capability (ESPC). The Navy's Earth System Prediction Capability (ESPC) is a program to develop next generation environmental prediction employing emerging technologies in physical coupled prediction across the air-sea interface as well as to land, near space, sea ice, and other physical interactions. Additionally, ensemble-based probabilistic prediction for informed decision making is being addressed and collaborations with other operational prediction agencies through common technology standards is being implemented to develop an improved coupled weather, ice, and ocean prediction across multiple time scales from tactical to strategic.

The Navy's ESPC will provide a more accurate, longer range, global ocean, atmosphere, and sea ice forecast system for decision support to safety of flight, safety of navigation, sensor and weapon performance, and mission planning, mitigation and effectiveness decisions. Development of global coupled ensemble technologies will provide increased accuracy for lead times of 1-10 days as well as a new capability for accurate forecasts from the Tropics into the Arctic at tactical, operational, and strategic lead times. It will develop a Navy interface to NOAA's products for seasonal to multi-annual lead times for deliberate planning through integrating atmosphere, ocean, ice, land and near-space forecast models into a seamless prediction system. This effort is the Navy contribution to a National ESPC for improved cross-Agency Research to Operations collaboration, and the development of more accurate forecast systems and more efficient computational architectures to allow for improved real-time operational prediction.

The Navy's ESPC directly enables achievement of warfighter decision superiority through improved knowledge of the physical environment. Such knowledge is key to the realization of Navy operational concepts critical to future warfighting capabilities such as the *Undersea Dominance Operating Concept* (UDOC) and *Electromagnetic Maneuver Warfare* (EMW). In both cases, knowledge of the current and future physical environment and its impact on the acoustic and electromagnetic spectrums directly supports the warfighter's ability to optimize courses of action and mitigate environmental operational impacts.

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 addresses a fleet requirement for real-time hazardous weather detection/display to support safety of flight and operations planning within Carrier and Expeditionary Strike Groups. The knowledge of hazardous weather conditions afloat greatly enhances readiness and combat posture.

Research and Development (R&D)

Naval METOC R&D is cooperatively sponsored by the Oceanographer/Navigator of the Navy and the Chief of Naval Research. 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. Both ONR and the Space and Naval Warfare Systems Command are 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 or selected missions.

Naval R&D efforts 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. Navy projects under sponsorship of the Oceanographer/Navigator of the Navy, transition from engineering development to operational naval systems. These efforts advance Naval METOC forecasting capabilities, communication enhancements, data compression techniques, to improve models and better predict METOC parameters in littoral regions. Our understanding of the impact these parameters have on sensors, weapons systems, and platforms is critical to mission success throughout the world. 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.

Research and Development (R&D) FY-17 Outlook

At present we anticipate no significant budget changes in FY 2017. Focus areas have been defined, using annual Sponsor/TYCOM guidance, Science and Technology Objectives (STOs), TYCOM Integrated Prioritized Capability List(s) and other references to influence the scope and direction of future R&D projects as well as the Basic and Applied Research that underpins Battlespace Awareness and Information Dominance technological innovation and operational transitions. Three thrust areas for US Navy meteorological R&D through FY 2017 include:

1. Expand or Atmospheric Boundary Layer Sensing Capability/Capacity to fully support Electro-magnetic Maneuver Warfare (EMW). Exploit Through-the-Sensor (TSS) opportunities and develop, field and sustain dedicated platforms/sensors capable of sufficiently resolving boundary layer structure.
2. Develop, Field and Sustain an Organic/Afloat Nowcasting Capability to support continuity of operations in an A2/AD environment. This 'Nowcast' model must be developed and fielded to support multiple computing environments, e.g., shipboard (CANES) and expeditionary.
3. Develop, Field and Sustain the Next-Generation Coupled Global Model and Infrastructure for Assured and Authoritative Access to Observations, Forecasts, Products, and Services. Refer to this link for Naval Research Laboratory, Monterey, CA http://www.nrlmry.navy.mil/

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 2016, the requested funding level is $30.0 million and 108 personnel authorizations (107 military and 1 Federal). The funding level for 2017 is not expected to change significantly. The Coast Guard does not have a specific program and budget for meteorology—all meteorological activities are accomplished as part of general operations. The USCG does not track meteorological costs at an organizational level, so the funding level is an estimate. 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) requested funding for FY 2016 is $4.9 million, 39 FTE, and 4 contractors which is a 4% increase over the total allocated from FY 2015. The 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). The FY 2016 budget request for SWA meteorological operations is estimated at $1.56 million and 10 FTE, which is the same amount allocated in FY 2015. The FY 2016 estimate includes $600,000 for labor and logistics to support climate and weather data collection efforts by BLM resource management staff, and approximately $965,000 for project implementation. Projects include 1) collection of meteorological data and operation of RAWS stations equipped with additional instruments to measure soil moisture and winter precipitation not required for fire monitoring, 2) maintenance of eight stations in the NRCS SCAN network, 3) operation of nine NADP sites, and 4) continued operation of a meteorological monitoring site at Inigok Station within the National Petroleum Reserve – Alaska. 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 when existing monitoring networks are not sufficient to meet the needs for air-resource-related information.

Fire and Aviation Directorate (FA). The FY 2016 FA budget request for meteorological operations is estimated at $3.3 million and 29 FTE, which is a 5.8 percent change from FY2015. This represents

BLM support for meteorologists at the National Interagency Coordination Center (NICC) and Geographic Area Coordination Centers (GACCs) and BLM support of the Interagency Remote Automatic Weather Station (RAWS) network. An additional $939,000 is generally 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. No change to the Soil Water and Air Management or Fire and Aviation Directorate program is anticipated in FY2017.

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) FY 2016 budget request is approximately $3.8 million, 8 FTE, and 3 contractors, essentially flat funding from FY 2015. The NPS expends about $0.9 million on atmospheric research with a focus on measurements of all forms of atmospheric reactive nitrogen and on aerosol science. The goal of this research is to identify the sources of air pollution that are affecting park ecosystems and visibility and to quantify their impacts. The NPS also expends approximately $2.9 million in routine air quality, visibility, and meteorological monitoring networks.

U.S. Geological Survey

The U.S. Geological Survey (USGS) requested funding for FY 2016 is estimated at approximately $63.7 million and 15 FTE, an increase of 2.7 percent from FY2015. This reflects funding requirements for the Geomagnetism Program, Hydrometeorological Data Collection and Distribution, and post-wildfire debris flow warning operations. No significant change is anticipated for FY 2017.

Geomagnetism Program. This request includes $2.15 million for magnetic observatory operations and monitoring and $1.4 million for research focused on ground-level hazards associated with variable space-weather conditions. The FY 2016 increase will provide for enhanced monitoring of geomagnetic and electric-field activity at ground level, and establish a national project for mapping time-dependent geomagnetic hazards for assessing national space weather vulnerability and risk.

Hydrometeorological Data Collection and Distribution and Post-wildfire debris flow warning operations. This request includes $60 million for operation of the national Stream Gage Network and $66K for post wildfire debris flow warning operations. The USGS's Water Mission Area 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. A number of federal, state, and local agencies contribute to the costs of collection and distribution of these data.

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration (FAA)

For FY 2016, the FAA is requesting a total of $374 million, 149 FTEs and 964 contractors for Aviation Weather related, Operations Support, Major Systems Acquisitions, Recurring Research and Development Costs, and Systems Development; an approximate 3.9% increase from FY 2015 actual funding received. The actual funding for the Aviation Weather Programs in FY 2015 was $360 million. The changes are comprised of:

- An increase in reported numbers for Operations Support from an actually received $262 million in FY 2015 to a requested $296 million in FY 2016.
- A decrease in reported numbers for Major Systems Acquisitions from an actually received $74.2 million in FY 2015 to a requested $51 million in FY 2016.
- An increase in reported numbers for recurring Research and Development Costs from an actually received $18.9 million in FY 2015 to a requested $22.4 million in FY 2016.
- No significant change in reported numbers for Systems Development from an actually received $5.4 million in FY 2015 to a requested $5.4 million in FY 2016.

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 enhancements, including the dissemination of weather products and decision-making information.

In FY 2015, FAA made an acquisition decision to build and deploy System-Wide Information Management (SWIM) – Common Support Services Weather (CSS-Wx) and NextGen Weather Processors (NWP) – Work Package 1. For FY 2017, we will continue to research and make progress in the weather area to support NextGen weather requirements. Research projects may include weather sensor/radar investment, weather needs in the flight deck and refresh of the weather infrastructure.

United States (U.S.) Code Title 49 Section 44720 (49 U.S.C. 44720) designates the FAA as the Meteorological Authority for domestic and international aviation weather services of the U.S. 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.

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 current transportation authorization allocates $100 million for the Intelligent Transportation Systems (ITS) Research Program. Of this, for FY 2016, the Road Weather Management Program (RWMP) has budgeted $2.0 million, 3 FTE, and 3 contractors. All of RWMP'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 and

connected vehicle data and products with transportation-oriented applications and management strategies.

Outlook for Fiscal Year 2017 – In addition to building out connected vehicle applications, which involves a driver, automated vehicle applications, which do not involve a driver, has been growing at a rapid pace. Most of the developments seem to have neglected road weather conditions, which is critical for enhancing safety, mobility and the environment. Much less is known about the effects of adverse weather on automated vehicle applications and there is significant need to research and understand these effects. It is the intention of the Road Weather Program to stay actively engaged in this research process to help support the development and deployment of automated vehicles.

ENVIRONMENTAL PROTECTION AGENCY

The anticipated funding level in FY 2016 for directed meteorological research is about $6.7 million and 43 FTE, and 12 contractors, a 4% increase from FY 2015. All of the Environmental Protection Agency's (EPA) funding of meteorological and air quality programs is for supporting basic and applied research. No significant change is anticipated for FY 2017 at this time.

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 supports a national research grants program 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 in FY 2016 is anticipated to be slightly less or comparable to that in FY 2015.

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 2016 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $6.69 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

The National Aeronautics and Space Administration's (NASA) estimated meteorological operations and research budget request for FY 2016 is $618.5 million, 10 FTEs, and 10 contractors. This request is an increase of 14.8 percent from the FY 2015 budget of $538.9 million. The budget figures reported

are based on relevant missions and programs in the Earth Science Division[1] and the Heliophysics Division[2] within the Science Mission Directorate (SMD), and the Human Exploration and Operations Mission Directorate (HEOMD)[3]. Across the directorates, NASA estimates the extent to which each mission and program contributes and relates to meteorological operations and research activities. For FY17, the only significant changes planned for NASA's meteorological operations and research activities concern the Heliophysics Division's phasing of development of the Solar Probe Plus and Solar Orbiter Collaboration missions.

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 program (which provides access to aircraft and unmanned aircraft systems), and supercomputing efforts supporting a variety of research areas. Most of the funds of the Earth Science Research program budget is competitively awarded to investigators from NASA centers, academia, other government agencies, and the private sector. 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: Improve the ability to predict climate changes by better understanding the roles and interactions of oceans, atmosphere, land, and ice in the climate system;
- Atmospheric Composition: Advance the understanding of changes in the Earth's radiation balance, air quality and the ozone layer that result from changes in atmospheric composition;
- Carbon Cycle and Ecosystems: Detect and predict changes in Earth's ecological and chemical cycles, including land cover, biodiversity, and the global carbon;
- Water and Energy Cycle: Enable better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change;
- Weather: Improve the capability to predict weather and extreme weather events; and
- Earth Surface and Interior: Characterize the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events.

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[1] The Earth Science Division (ESD) reported budget includes an estimate of weather observations and research and closely related program activities. Research and satellite mission budgets are estimated proportionally to their overall contributions to activities reported, noting that the objective of ESD's program is to advance Earth System science.

[2] This report includes Heliophysics Division research assets and programs that contribute significantly to the advancement of space weather knowledge and to the transfer of that knowledge into space weather prediction systems.

[3] The Human Exploration and Operations Mission Directorate (HEOMD) reported budget includes an estimate of activities to measure and forecast atmospheric and space weather events that strongly impact launch and landing operations, as well as crew radiation exposure.

NASA also supports space weather research through the Heliophysics Division within NASA's SMD. The objective of the Heliophysics Division is to understand the Sun and its interactions with the Earth and the solar system, including space weather. To that end, the NASA Heliophysics program seeks to perform innovative space research missions to understand:

- What causes the Sun to vary?
- How do the geospace, planetary space environments and the heliosphere respond?
- What are the impacts on humanity?

Heliophysics also seeks to enable research based on these missions and other sources to understand the connections among the Sun, Earth, and the solar system for science and to assure human safety and security both on Earth and as we explore beyond it. Heliophysics research provides a foundation to build predictive models of space weather events, mitigate the hazards posed to assets both in space and on the ground, and understand space weather impacts throughout the solar system.

In addition to research, NASA also engages in operations regarding atmospheric and space weather constraints within the HEOMD. The HEOMD objective is the safety of manned spacecraft, crew, satellites, scientific instruments, and launch vehicles. The greatest challenge is to accurately measure and forecast atmospheric and space weather events that strongly impact all operational phases of the mission, as well as crew radiation exposure.

NUCLEAR REGULATORY COMMISSION

For FY 2016, the Nuclear Regulatory Commission's (NRC) total planned contract expenditures of $1.87 million ($480,000 for operations and $1.39 million for supporting research) and 7 FTE are for meteorological operations to continue:

- technical assistance for the analysis of atmospheric transport and dispersion for routine and postulated accidental releases from nuclear facilities
- conducting meteorological research in support of licensing activities, including consideration of site specific probable maximum precipitation analysis and local intense precipitation analysis related to hydrometeorology at certain facilities
- updating and preparing guidance on meteorological subjects pertaining to licensing actions
- reviews of proposed sites for possible construction of new nuclear power plants
- reviews of meteorological parameters for submitted design certification applications
- reviews of existing sites and meteorological parameters for operating facilities (reactors, production and utilization facilities, storage facilities)

The meteorological support program at the NRC includes analyzing and employing 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 in order 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 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. This work was continued in FY 2013 and FY 2014 and is prioritized to continue into the coming fiscal year for those areas of the United States where new nuclear power plants are proposed or where existing nuclear power plants are utilizing these concepts. The four key regulatory applications to be focused on include support of new reactor licensing, support of reactor oversight process, support of risk-informed licensing actions, and support of future regulatory actions related to flooding. This work will provide the design basis for flood protection systems and plant response for nuclear power plants.

The nuclear power industry continues to operate existing facilities, as well as pursue approval for new nuclear power plants. Numerous license amendments for existing sites and early site permit, combined license, and design certification applications have been received and are currently under review or have been approved by the NRC. These reviews consider site characteristics, regional climatology, and local meteorology. In addition to its internal activities, the NRC seeks assistance from other Federal agencies to support its safety and environmental licensing actions.

In addition, due to the March 2011 earthquake and subsequent tsunami accident at the Fukushima Dia-ichi nuclear power plant, NRC licensees were requested to provide their responses to their reevaluations of flooding hazards at their sites (using updated information, methodologies, and regulatory guidance) on a staggered three-year basis, beginning in March 2013. The NRC staff, along with support from its consultants, has begun reviewing these flood hazard reevaluations. In addition, NRC staff has received several accompanying site-specific probable maximum precipitation analyses that are being used by licensees to determine whether additional regulatory actions are necessary to protect the site against the reevaluated flooding hazards. These licensees are making predictions for maximum precipitation using similar methods to those utilized in the NWS HMRs but with new assumptions (e.g. storm catalogs, maximum moisture results, and storm transposition). The licensees are requesting that the NRC provide a licensing decision on these new methods regarding the adequacy of these methods. As part of this effort, the NRC is engaging with other federal agencies and experts in this field to observe how these analyses compare to NOAA's existing HMRs and what acceptance criteria the NRC should apply to determine the licensing acceptability of these methods.

DEPARTMENT OF ENERGY

DOE's Climate and Environmental Sciences Division (CESD) focuses on a predictive, systems-level understanding of the fundamental science associated with climate change and DOE's environmental challenges; both are key to support the DOE science mission. As a basic science funding organization within the DOE Office of Science, CESD does not provide climate services to federal, state, and local agencies nor does it conduct research for the purpose of improved operations or climate services. Through its support for basic research, DOE CESD contributes to the fundamental understanding of the climate system. [See Table 1, page 46, Chapter 5 Budget Information, FY 2014 – FY 2016 USGCRP Budget Crosscut by Agency, "The U.S. Global Change Research Program for Fiscal Year 2016", A Supplement to the President's Budget, of the "Our Changing Planet", National Science Foundation Award No. NSFDACS13C1421.]

DEPARTMENT OF STATE

The Department of State (DOS) request for funding related to meteorological services and supporting research in the FY 2016 President's Budget is an estimated $2.8M, consistent with funds dispersed for FY 2015. Requested FY 2016 funds would allow DOS to continue to contribute funding for activities related to Intergovernmental Panel on Climate Change (IPCC), an organization to assess scientific, technical, and socioeconomic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation. This funding also supports DOS contributions to the Global Earth Observations and Global Climate Observing System programs. No significant funding changes are anticipated for FY 2017 at this time.

SMITHSONIAN INSTITUTION

Global Volcanism Program (GVP). The Smithsonian Institution requested funding for FY 2016 is an estimated $70K and 2 FTE to support the Natural History Museum, Global Volcanism Program. This represents no significant change from the total allocated for FY 2015 and there is no significant change anticipated for FY 2017. The GVP collects, catalogs, and disseminates information on ~1,540 volcanoes active in the last 10,000 years with a small staff working regular business hours Monday to Friday in the Natural History Museum in Washington, D.C.

NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) request for funding related to meteorological supporting research in the FY 2016 President's Budget is $135.9M, and 10 FTE, a 4.7% increase over FY 2015. Requested FY 2016 funds would allow NSF to continue to fund research related to basic meteorology, climate, and space weather. NSF proposal requests are community-driven, which allows funding to move to emerging areas of interest. In addition, the funding would ensure that facilities, both observational and computational, are made available for community use. No major changes are currently anticipated for FY 2017.

BUDGET TABLES

Table 1 Meteorological Operations and Supporting Research Costs* by Agency

This table summarizes, by agency, *both* meteorological operations and supporting research costs. Funding levels for FY 2015 are congressionally appropriated funds. FY 2016 numbers indicate the funding requested in the President's FY 2016 budget. The change percentages between FY 2015 and FY 2016 are also shown.

TABLE 1 Meteorological Operations and Supporting Research Costs* by Agency

(Thousands of Dollars)

	Operations			% of FY16	Supporting Research			% of FY16	Total			% of FY15	% of FY16
AGENCY	FY15	FY16	%CHG	TOTAL	FY15	FY16	%CHG	TOTAL	FY15	FY16	%CHG	TOTAL	TOTAL
Agriculture	20100	19951	-0.7	0.5	54909	55169	0.5	4.9	75009	75120	0.1	1.5	1.4
Commerce/NOAA(Subtot)	3332491	3494335	4.9	83.3	191793	216262	12.8	19.2	3524284	3710597	5.3	70.1	69.7
NWS	1072460	1076765	0.4	25.7	14993	22113	47.5	2.0	1087453	1098878	1.1	21.6	20.6
NESDIS	2197144	2353311	7.1	56.1	26000	26316	1.2	2.3	2223144	2379627	7.0	44.2	44.7
OAR	0	0	0	0	150800	167833	11.3	14.9	150800	167833	11.3	3.0	3.2
NOS	31287	31966	2.2	0.8	0	0	0	0	31287	31966	2.2	0.6	0.6
OMAO	31600	32293	2.2	0.8	0	0	0	0	31600	32293	2.2	0.6	0.6
Defense(Subtot)	237584	230759	-2.9	5.5	50757	64014	26.1	5.7	288341	294773	2.2	5.7	5.5
Air Force	110412	111231	0.7	2.7	20102	29955	49.0	2.7	130514	141186	8.2	2.6	2.7
Navy	113307	105113	-7.2	2.5	17006	21742	27.8	1.9	130313	126855	-2.7	2.6	2.4
Army	13865	14415	4.0	0.3	13649	12317	-9.8	1.1	27514	26732	-2.8	0.5	0.5
Homeland Security (Subtot)	29887	29970	0.3	0.7	0	0	0	0	29887	29970	0.3	0.6	0.6
USCG	29887	29970	0.3	0.7	0	0	0	0	29887	29970	0.3	0.6	0.6
Interior/BLM (Subtot)	68791	69983	1.7	1.7	1676	2336	39.4	0.2	70467	72319	2.6	1.4	1.4
BLM	4684	4865	3.9	0.1	0	0	0	0	4684	4865	3.9	0.1	0.1
NPS	2889	2900	0.4	0.1	940	900	-4.3	0.1	3829	3800	-0.8	0.1	0.1
USGS	61218	62218	1.6	1.5	736	1436	95.1	0.1	61954	63654	2.7	1.2	1.2
Transportation(Subtot)	336223	346641	3.1	8.3	26260	29769	13.4	2.6	362483	376410	3.8	7.2	7.1
FAA	336223	346641	3.1	8.3	24260	27769	14.5	2.5	360483	374410	3.9	7.2	7.0
FHWA	0	0	0	0	2000	2000	0.0	0.2	2000	2000	0.0	0.0	0.0
EPA	0	0	0	0	6430	6690	4.0	0.6	6430	6690	4.0	0.1	0.1
NASA	1973	2035	3.1	0.0	536909	616465	14.8	54.6	538882	618500	14.8	10.7	11.6
NRC	337	480	42.4	0.0	1390	1390	0.0	0.1	1727	1870	8.3	0.0	0.0
DOE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOS	2800	2800	0.0	0.1 0	0	0	0	0	2800	2800	0.0	0.1	0.1
Smithsonian	15	0	-100.0	0	55	70	27.3	0.0	70	70	0.0	0.0	0.0
NSF	0	0	0	0	129791	135891	4.7	12.0	129791	135891	4.7	2.6	2.6
TOTAL	4030201	4196954	4.1	100.0	999970	1128056	12.8	100.0	5030171	5325010	5.9	100.0	100.0
% of FY TOTAL	80.1%	78.8%			19.9%	21.2%			100.0%	100.0%			

*The FY 2015 funding reflects Congressionally appropriated funds; the FY 2016 funding reflects the amount requested in the President's FY 2016 budget submission to Congress.

Table 2 Operational Costs by Budget Category

This table describes the agency plans 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 FY16
AGENCY	FY15	FY16	FY15	FY16	FY15	FY16	%CHG	TOTAL
Agriculture	20100	19951	0	0	20100	19951	-0.7	0.5
Commerce/NOAA(Subtot)	1176647	1178387	2155844	2315948	3332491	3494335	4.9	83.3
NWS	951160	950100	121300	126665	1072460	1076765	0.4	25.7
NESDIS	162600	164028	2034544	2189283	2197144	2353311	7.1	56.1
OAR	0	0	0	0	0	0	0	0
NOS	31287	31966	0	0	31287	31966	2.2	0.8
OMAO	31600	32293	0	0	31600	32293	2.2	0.8
Defense(Subtot)	188704	177092	48880	53667	237584	230759	-2.9	5.5
Air Force	80338	80900	30074	30331	110412	111231	0.7	2.7
Navy	96301	83377	17006	21736	113307	105113	-7.2	2.5
Army	12065	12815	1800	1600	13865	14415	4.0	0.3
Homeland Security (Subtot)	29887	29970	0	0	29887	29970	0.3	0.7
USCG	29887	29970	0	0	29887	29970	0.3	0.7
Interior/BLM	68791	69983	0	0	68791	69983	1.7	1.7
BLM (Subtot)	4684	4865	0	0	4684	4865	3.9	0.1
SWA	1565	1565	0	0	1565	1565	0.0	0.0
OFA	3119	3300	0	0	3119	3300	5.8	0.1
NPS	2889	2900	0	0	2889	2900	0.4	0.1
USGS	61218	62218	0	0	61218	62218	1.6	1.5
Transportation(Subtot)	262003	295641	74220	51000	336223	346641	3.1	8.3
FAA	262003	295641	74220	51000	336223	346641	3.1	8.3
FHWA	0	0	0	0	0	0	0	0
EPA	0	0	0	0	0	0	0	0
NASA	1973	2035		0	1973	2035	3.1	0.0
NRC	337	480	0	0	337	480	42.4	0.0
DOE	0	0	0	0	0	0	0	0
DOS	2800	2800	0	0	2800	2800	0.0	0.1
Smithsonian	15	0	0	0	15	0	-100.0	0
NSF	0	0	0	0	0	0	0	0
TOTAL	1751257	1776339	2278944	2420615	4030201	4196954	4.1	100.0
% of FY TOTAL	43.5%	42.3%	56.5%	57.7%	100.0%	100.0%		

Table 3 Supporting Research and Development Costs by Budget Category

This table describes the agency plans to obligate their funds for *meteorological supporting research and Development* by budget category. Similar to operational funding in table 2, these categories are Research and Development (non-hardware) and Systems Development (hardware).

TABLE 3 Supporting Research and Development Costs by Budget Category

(Thousands of Dollars)

AGENCY	Recurring R&D Costs FY15	Recurring R&D Costs FY16	Systems Development FY15	Systems Development FY16	Total FY15	Total FY16	%CHG	% of FY16 TOTAL
Agriculture	54909	55169	0	0	54909	55169	0.5	4.9
Commerce/NOAA(Subtot)	189273	214392	2520	1870	191793	216262	12.8	19.2
NWS	14343	22113	650	0	14993	22113	47.5	2.0
NESDIS	26000	26316	0	0	26000	26316	1.2	2.3
OAR	148930	165963	1870	1870	150800	167833	11.3	14.9
NOS	0	0	0	0	0	0	0	0
OMAO	0	0	0	0	0	0	0	0
Defense(Subtot)	32611	46956	18146	17058	50757	64014	26.1	5.7
Air Force	5002	15005	15100	14950	20102	29955	49.0	2.7
Navy	17006	21742	0	0	17006	21742	27.8	1.9
Army	10603	10209	3046	2108	13649	12317	-9.8	1.1
Homeland Security (Subtot)	0	0	0	0	0	0	0	0
USCG	0	0	0	0	0	0	0	0
Interior/BLM	1676	2336	0	0	1676	2336	39.4	0.2
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	940	900	0	0	940	900	-4.3	0.1
USGS	736	1436	0	0	736	1436	95.1	0.1
Transportation(Subtot)	20895	24369	5365	5400	26260	29769	13.4	2.6
FAA	18895	22369	5365	5400	24260	27769	14.5	2.5
FHWA	2000	2000	0	0	2000	2000	0.0	0.2
EPA	6430	6690	0	0	6430	6690	4.0	0.6
NASA	152565	163942	384344	452523	536909	616465	14.8	54.6
NRC	1390	1390	0	0	1390	1390	0.0	0.1
DOE	0	0	0	0	0	0	0	0
DOS	0	0	0	0	0	0	0	0
Smithsonian	35	50	20	20	55	70	27.3	0.0
NSF	129791	135891	0	0	129791	135891	4.7	12.0
TOTAL	589575	651185	410395	476871	999970	1128056	12.8	100.0
% of FY TOTAL	59.0%	57.7%	41.0%	42.3%	100.0%	100.0%		

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

These tables indicate how the funds identified in Tables 2 and 3 are divided among the eleven service categories. Table 4 reflects how the agencies plan to obligate operational funds and Table 5 supporting research funds. The service categories evolve over time, as applications change with technology and with societal needs. 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 dispersion (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, space systems, Earth's atmosphere, and the space environment. Space weather services include monitoring and alerting of space weather storms and their effects on technological infrastructure and human safety. 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 FY15	Basic Services FY16	Agriculture & Land Management FY15	Agriculture & Land Management FY16	Aviation FY15	Aviation FY16	Climate FY15	Climate FY16	Emergency Response & Homeland Security FY15	Emergency Response & Homeland Security FY16	Hydrometeorology & Water Resources FY15	Hydrometeorology & Water Resources FY16	Military FY15	Military FY16	Space Weather FY15	Space Weather FY16	Surface Transportation FY15	Surface Transportation FY16	Wildland Fire Weather FY15	Wildland Fire Weather FY16	Other Specialized FY15	Other Specialized FY16	Total FY15	Total FY16
Agriculture	0	0	2610	2623	0	0	0	0	0	0	9265	8902	0	0	0	0	0	0	8225	8426	0	0	20100	19951
Commerce/NOAA(Subtot)	3061200	3186225	0	0	65293	71694	31442	47516	0	0	82690	97569	0	0	8840	11926	31287	31966	38029	38789	13710	8650	3332491	3494335
NWS	833564	802032	0	0	65293	71694	31442	47516	0	0	81582	96158	0	0	8840	11926	0	0	38029	38789	13710	8650	1072460	1076765
NESDIS	2197144	2353311	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2197144	2353311
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	31287	31966	0	0	0	0	31287	31966
OMAO	30492	30882	0	0	0	0	0	0	0	0	1108	1411	0	0	0	0	0	0	0	0	0	0	31600	32293
Defense(Subtot)	1650	1688	0	0	444	454	110	113	0	0	0	0	222869	214887	12511	13617	0	0	0	0	0	0	237584	230759
Air Force	0	0	0	0	0	0	0	0	0	0	0	0	97901	97614	12511	13617	0	0	0	0	0	0	110412	111231
Navy	0	0	0	0	0	0	0	0	0	0	0	0	113307	105113	0	0	0	0	0	0	0	0	113307	105113
Army	1650	1688	0	0	444	454	110	113	0	0	0	0	11661	12160	0	0	0	0	0	0	0	0	13865	14415
Homeland Security (Subtot)	0	0	0	0	0	0	0	0	29887	29970	0	0	0	0	0	0	0	0	0	0	0	0	29887	29970
USCG	0	0	0	0	0	0	0	0	29887	29970	0	0	0	0	0	0	0	0	0	0	0	0	29887	29970
Interior/BLM	0	0	0	0	0	0	1565	1565	0	0	60000	60000	0	0	1152	2152	0	0	3185	3366	2889	2900	68791	69983
BLM (Subtot)	0	0	0	0	0	0	1565	1565	0	0	0	0	0	0	0	0	0	0	3119	3300	0	0	4684	4865
SWA	0	0	0	0	0	0	1565	1565	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1565	1565
OFA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3119	3300	0	0	3119	3300
NPS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2889	2900	2889	2900
USGS	0	0	0	0	0	0	0	0	0	0	60000	60000	0	0	1152	2152	0	0	66	66	0	0	61218	62218
Transportation(Subtot)	0	0	0	0	336223	346641	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	336223	346641
FAA	0	0	0	0	336223	346641	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	336223	346641
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	800	800	0	0	0	0	1173	1235	1973	2035
NRC	0	0	0	0	0	0	0	0	0	0	257	400	0	0	0	0	0	0	0	0	80	80	337	480
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
DOS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2800	2800	2800	2800
Smithsonian	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0
NSF	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	3062850	3187913	2610	2623	401960	418789	33117	49194	29902	29970	152212	166871	222869	214887	23303	28495	31287	31966	49439	50581	20652	15665	4030201	4196954
% of FY TOTAL	76.0%	76.0%	0.1%	0.1%	10.0%	10.0%	0.8%	1.2%	0.7%	0.7%	3.8%	4.0%	5.5%	5.1%	0.6%	0.7%	0.8%	0.8%	1.2%	1.2%	0.5%	0.4%	100.0%	100.0%

TABLE 5 Supporting Research and Development Costs by Service Category
(Thousands of Dollars)

AGENCY	Basic Services FY15	Basic Services FY16	Agriculture & Land Management FY15	Agriculture & Land Management FY16	Aviation FY15	Aviation FY16	Climate FY15	Climate FY16	Emergency Response & Homeland Security FY15	Emergency Response & Homeland Security FY16	Hydrometeorology & Water Resources FY15	Hydrometeorology & Water Resources FY16	Military FY15	Military FY16	Space Weather FY15	Space Weather FY16	Surface Transportation FY15	Surface Transportation FY16	Wildland Fire Weather FY15	Wildland Fire Weather FY16	Other Specialized FY15	Other Specialized FY16	Total FY15	Total FY16
Agriculture	0	0	14982	14709	0	0	32481	33088	0	0	35	35	0	0	0	0	0	0	7411	7337	0	0	54909	55169
Commerce/NOAA(Subtot)	113066	127535	0	0	2250	2250	60000	70494	1025	1025	14052	14308	0	0	750	0	0	0	0	0	650	650	191793	216262
NWS	12968	20838	0	0	625	625	0	0	0	0	0	0	0	0	750	0	0	0	0	0	650	650	14993	22113
NESDIS	26000	26316	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26000	26316
OAR	74098	80381	0	0	1625	1625	60000	70494	1025	1025	14052	14308	0	0	0	0	0	0	0	0	0	0	150800	167833
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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Defense(Subtot)	10603	10209	0	0	1700	857	1346	1251	0	0	0	0	30625	47697	6483	4000	0	0	0	0	0	0	50757	64014
Air Force	0	0	0	0	0	0	0	0	0	0	0	0	13619	25955	6483	4000	0	0	0	0	0	0	20102	29955
Navy	0	0	0	0	0	0	0	0	0	0	0	0	17006	21742	0	0	0	0	0	0	0	0	17006	21742
Army	10603	10209	0	0	1700	857	1346	1251	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13649	12317
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	736	1436	0	0	0	0	940	900	1676	2336
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	940	900	940	900
USGS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	736	1436	0	0	0	0	0	0	736	1436
Transportation(Subtot)	0	0	0	0	24260	27769	0	0	0	0	0	0	0	0	0	0	2000	2000	0	0	0	0	26260	29769
FAA	0	0	0	0	24260	27769	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24260	27769
FHWA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2000	2000	0	0	0	0	2000	2000
EPA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6430	6690	6430	6690
NASA	0	0	0	0	0	0	260605	255734	0	0	0	0	0	0	274792	359659	0	0	697	472	815	600	536909	616465
NRC	0	0	0	0	0	0	0	0	650	650	740	740	0	0	0	0	0	0	0	0	0	0	1390	1390
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
DOS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smithsonian	0	0	0	0	0	0	0	0	55	70	0	0	0	0	0	0	0	0	0	0	0	0	55	70
NSF	59402	62194	0	0	0	0	50189	52548	0	0	0	0	0	0	20200	21149	0	0	0	0	0	0	129791	135891
TOTAL	183071	199938	14982	14709	28210	30876	404621	413115	1730	1745	14827	15083	30625	47697	302961	386244	2000	2000	8108	7809	8695	8040	999970	1128056
% of FY TOTAL	18.3%	17.7%	1.5%	1.3%	2.8%	2.7%	40.5%	36.6%	0.2%	0.2%	1.5%	1.3%	3.1%	4.2%	30.3%	34.2%	0.2%	0.2%	0.8%	0.7%	0.9%	0.8%	100.0%	100.0%

Table 6 Personnel Supporting Meteorological Operations and Research

This table includes both current and FY 2016 requested personnel (Federal (FTE), Contractor, Military) required to perform or support meteorological operations and supporting research. The total federal agency staffing requested for FY 2016 is 13,839.

Agency		Federal	Contractor	Military*	Current FY 2015	Federal	Contractor	Military*	Requested FY 2016	%CHG	% of FY 16 TOTAL
Agriculture		103	8	0	111	94	6	0	100	-9.9	0.7
Commerce/NOAA	Subtotal	6161	1091	0	7252	6079	2001	0	8080	11.4	58.4
NWS		4638	741	0	5379	4540	786	0	5326	-1.0	38.5
NESDIS		885	87	0	972	885	951	0	1836	88.9	13.3
OAR**		402	201	0	603	416	201	0	617	2.3	4.5
NOS		115	62	0	177	117	63	0	180	1.7	1.3
OMAO		121	0	0	121	121	0	0	121	0.0	0.9
Defense	Subtotal	562	105	3733	4400	502	103	3679	4284	-2.6	31.0
Air Force		440	66	2948	3454	380	63	2894	3337	-3.4	24.1
Navy		75	18	415	508	75	18	415	508	0.0	3.7
Marine Corps		0	0	370	370	0	0	370	370	0.0	2.7
Army		47	21	0	68	47	22	0	69	1.5	0.5
Homeland Security-USCG		1	0	107	108	1	0	107	108	0.0	0.8
Interior/BLM	Subtotal	46	7	0	53	47	7	0	54	1.9	0.4
BLM Soil/Water/Air Program		10	0	0	10	10	0	0	10	0.0	0.1
BLM Fire Weather Program		28	4	0	32	29	4	0	33	3.1	0.2
NPS		8	3	0	11	8	3	0	11	0.0	0.1
USGS		12	0	0	12	15	0	0	15	25.0	0.1
Transportation	Subtotal	152	967	0	1119	152	967	0	1119	0.0	8.1
FHWA		3	3	0	6	3	3	0	6	0.0	0.0
FAA		149	964	0	1113	149	964	0	1113	0.0	8.0
EPA		41	12	0	53	43	12	0	55	3.8	0.4
NASA		10	10	0	20	10	10	0	20	0.0	0.1
NRC		7	0	0	7	7	0	0	7	0.0	0.1
DOE		0	0	0	0	0	0	0	0	0	0
DOS		0	0	0	0	0	0	0	0	0	0
Smithsonian		2	0	0	2	2	0	0	2	0.0	0.0
NSF		10	0	0	10	10	0	0	10	0.0	0.1
Totals					13135				13839	5.4	100.0

* Active Duty (does not include National Guard or Reserve)

** all research

Table 7 Interagency Fund Transfers

This table summarizes the reimbursement of funds from one agency to another during FY 2015. Agencies routinely enter into reimbursable agreements when they determine an agency can provide a given activity more cost-effectively. While specific activities and amounts may vary from year-to-year, the pattern reflects a significant level of interagency cooperation.

	FY2015 Funds ($K) Estimated or Planned			
Transferred from:	**To:**	**Operations**	**Supporting Research**	
DOC/NOAA				
NESDIS/NCEI	NASA/LaRC/DEVELOP	75	0	
NESDIS/NCEI	NASA/LaRC	75	0	
NESDIS/NCEI	NRL	50	0	
NESDIS/WALLOPS	NASA	543	0	
NOAA/NESDIS/FBANKS	DOD/ARMY	11	0	
OAR	DOE		4076	
OAR	USDA		231	
DHS				
USFA	DOI/BLM-FA	0		Lightning
FEMA	DOC/NOAA/NESDIS/NCEI	100		
USDA				
USDA/USFS	DOI/BLM-OFA	649		RAWS maintenance contracts
USDA/USFS	DOI/BLM	20		Lightning
USDA/NRCS	USDA/USFS	43		Snow Survey support
USDA/NRCS	DOI	57		Snow Survey support
USDA/NRCS	DOI/NPS	2		Snow Survey support
DOD				
SERDP	DOC/NOAA/NESDIS/NCEI	0	251.3	
Air Force	DOC/NOAA/NESDIS	15249		
Air Force	DOC/NOAA/NWS	4089	615	
Air Force	DOC/OFCM	145		
Air Force	DOI/USGS	432		
Air Force	NASA	380		
Air Force	NSF/UCAR/NCAR		1020	
Navy	DOC/NOAA/OAR			
Army	OFCM			
USACE	NOAA/NWS	205		
USACE	DOI/USGS	20085		
USACE	USDA			NRCS
USACE	DOC/NOAA/OAR			
DOD	DOI/BLM OFA	17		
DOI				
USGS	DOC/NOAA/NESDIS/NCEI	0	3.5	
USGS	DOC/NOAA/NESDIS	390		
DOI/BLM	DOC/NOAA/NESDIS	15		
DOI/BLM SWA	USDA-NIFA	62		
DOI/BLM SWA	USDA	50		NRCS
USGS	DOC/NOAA/OAR		100	
DOI/NPS	USDA	20		NRCS
DOI/NPS	USDA	336		National Atmospheric Deposition Program
DOI/NPS	EPA	256		CASTNet Filter Pack Analysis
DOI/BOR	USDA	43		NRCS
DOI/NPS	USDA	397		National Atmospheric Deposition Program
DOI/NPS	EPA	288		CASTNet Filter Pack Analysis
DOI/BOR	USDA			NRCS
DOI	DOC/NOAA/OAR		35	
DOI/BLM SWA	USDA-NIFA	62		
DOI/BLM SWA	USDA	50		NRCS
DOT				
FAA Weather	DOC/NOAA/NWS	13653		IAA-Center Weather Service Unit
FAA Weather	DOC/NOAA/NWS	65		IAA
DOT	DOC/NOAA/OAR		446	
NASA				
NASA/GSFC	DOC/NOAA/NESDIS/NCEI	0	181.6	
NASA GSIF	DOC/NOAA/NESDIS	90		
	DOD/USAF/45th Space Wing	800	0	
	DOC/NOAA/NDBC	50		
DOE	DOC/NOAA/OAR		2481	
State/Local	USDA	284		NRCS
	DOI/BLM-FA	238		RAWS maintenance contracts

Table 8 Facilities/Locations/Systems Taking Meteorological Observations

This table shows the number of facilities/locations/systems at which the Federal agencies carry out or oversee the taking of various types of meteorological observations.

TABLE 8 Facilities/Locations/Systems Taking Meteorological Observations

TYPE OF OBSERVATION by AGENCY	No. of 2015 Locations	
Surface, land		
Commerce (NOAA/NWS all types)	29315	ASOS: 315 COOP: 9000 MESONET: 20000
Commerce (NOAA/OAR manned Atmospheric Baseline Observations)	6	
Commerce (NOAA/OAR Climate Reference Network)	114	
Commerce (NOAA/NWS/INL Mesonet)	35	Idaho National Laboratory (INL) Mesonest used by Pocatello Weather Service Forecast Office. 35 according to the NOSC.
Commerce (NOAA/NWS Weather Monitoring Stations)	16	
Commerce (NOAA/OAR/ARL SORD Mesonet)	22	Special Operations And Research Division (SORD)
Air Force (U.S. & Overseas)	184	
Navy (U.S. & Overseas)	68	
Marine Corps (U.S. & Overseas)	24	
Army (U.S. & Overseas)	23	
Transportation (FAA Contract Wx Obsg Stn)*	136	
Transportation (FAA Auto Wx Obsg Stn - AWOS)	188	
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)	2437	
Homeland Security (USCG Coastal)	50	
Interior (NPS Air Program)	32	
Interior (BLM Soil/Water/Air Program)	481	
Interior (BLM Office of Fire and Aviation)	991	
Interior (USGS Geomagnetic Program)	14	
Agriculture (NRCS active manual snow courses)	1112	

Agriculture (NRCS automated SNOTEL stations)		856	
Agriculture (NRCS automated SNOLITE stations)		22	
Agriculture (NRCS automated SCAN stations)		220	
Agriculture (Agricultural Research Service)		26	
Forest Service Smoke Monitors		49	
Forest Service RAWS		964	
Forest Service (Research)		98	
NASA (All Types)		1	
	Total	38116	

*Note: All 136 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 (NOAA/NOS/SEAS-equipped ships)		622	
Commerce (NOAA/NOS/PORTS)		67	stations with met sensors
Commerce (NOAA/NOS/NWLON)		180	stations with met sensors
Commerce (NOAA/NWS Coastal-Marine Autom Network)		47	
Commerce (NOAA/NWS/NDBC Buoys--moored)		101	does not include TAO and DART
Commerce (NOAA/OAR/AOML Buoys--drifting)		1238	
Navy (Ships with met personnel)		29	
Navy (Ships without met personnel)		259	
Homeland Security (USCG Cutters)		249	
	Total	2792	

Upper air, balloon

Commerce (NOAA/NWS U.S.)		92	
Commerce (NOAA/NWS Foreign, Cooperative)		10	Cooperative Hurricane Upper-Air Stations (CHUAS)
Commerce (NOAA/NWS met/ozone/water vapor)		135	Note: There has been a significant increase in aircraft observation systems compared to 25 last year
Air Force, Mobile		1	
Army, Fixed (U.S. & Overseas)		10	
Army, Mobile (U.S. and Overseas)		8	
Navy, Fixed (U.S. & Overseas)			
Navy, Mobile(U.S. & Overseas)			

Navy, Ships			
Marine Corps, Mobile		13	
	Total	269	
Atmospheric Profilers			
Commerce (NOAA/NWS) (404 and 449 MHz)		39	
Air Force (Eastern Range) (915 MHz)			
Air Force (Eastern Range) (SODARS)			
Air Force (Western Range) (915 MHz)			
Air Force (Western Range) (50 MHz)			
Air Force (Western Range SODARS)			
Army		6	
NASA (50 MHz)		1	
Doppler weather radar (WSR-88D) sites			
Commerce (NOAA/NWS)		122	
Air Force (U.S. & Overseas)		26	
Transportation-FAA (Off CONUS)		13	
	Total	161	
Doppler weather radar (Not WSR-88D) sites			
Air Force (Fixed, Deployed))		20	
Army		3	
Navy (Fixed)			
Commerce (NOAA/NWS Research Phased Array Radar- NWRT)		1	
	Total	24	
Airport Terminal Doppler weather radars			
Transportation-FAA (Commissioned)		45	
	Total	45	
Conventional radar (non-Doppler) sites			
Commerce (NOAA/NWS)		0	legacy radars removed in 2013
Air Force, Mobile Units			
Army (U.S. and Overseas)			
Transportation (FAA (WSP))		34	
	Total	34	
Off-site WSR-88D Principle User Processors (PUPs)			
Air Force (OPUPs only)		7	
Marine Corps (U.S. & Overseas)			
Army			
	Total	7	
Weather reconnaissance Aircraft			
Commerce (NOAA/OMAO)		3	
Air Force Reserve Command (AFRC) - WC-130J		10	
	Total	13	

Geostationary meteorological satellites (No. operating)			
GOES 12 - South America		Decommissioned	
GOES 13 - Operational East		1	
GOES 14 - On-Orbit Storage		1	
GOES 15 - Operational West		1	
NESDIS	Total	3	http://www.oso.noaa.gov/goesstatus/
Polar meteorological satellites (No. operating)			
METOP-B - AM Primary		1	
METOP-A - AM Backup		1	
NOAA 15 - AM Secondary		1	
NOAA 16 - PM Secondary		Decommissioned	
NOAA 17 - AM Backup		Decommissioned	
NOAA 18 - PM Secondary		1	
NOAA 19 - PM Prime Service Mission		1	
SNPP - PM Primary		1	
NESDIS	Sub-Total	6	http://www.oso.noaa.gov/poesstatus/
Air Force (2 primary, 2 secondary, 2 tactical)		6	
Navy (WINDSAT and GFO)		1	
	Total	13	
Electric Field Mills (Surface)			
Army		5	
	Total	6	
Lightning Detection Systems			
Air Force (Eastern and Western Range Cloud-Ground)		2	
Air Force (Eastern and Western Range-NLDN & Total Ltng Sys)		2	
Army		6	
	Total	10	
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 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 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.

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.

OFCM COORDINATING INFRASTRUCTURE

The OFCM coordinating infrastructure diagram on page 2-5 shows the current committees, working groups (WG), and joint action groups (JAG) through which OFCM carries out its mission of ensuring the effective use of Federal meteorological resources by coordinating operational weather requirements, services, and supporting research among the Federal agencies. FCMSSR is shown at the top of the diagram, as the policy guidance advisor to its subordinate elements and the Federal Coordinator.

- The Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) is the primary Executive-level management body of the Federal coordinating structure. ICMSSR provides advice to OFCM, implements FCMSSR policies, and oversees the committees and working groups that address observing systems, weather operations and services, operational processing centers, and automated weather information systems. The full membership of ICMSSR is shown on the inside cover of this Federal Plan.
- Program Councils can be established under ICMSSR to coordinate key programs or mission areas to ensure they meet interagency needs. Additionally, 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. Currently, all Program Council functions are being conducted by the ICMSSR.
- The committees, working groups, and joint action groups operate at the program and working levels to provide: (1) a forum for each agency to report activities, challenges, and achievements; (2) a mechanism to coordinate change and problem solving; (3) a way to collect, document, and consolidate agency requirements and inventories; (4) oversight for coordinated system development; (5) a vehicle for coordinating with other groups internal and external to the coordinating infrastructure; and (6) a mechanism for the preparation of studies, agreements, standards, protocols, reports, and national plans. Working Groups are intended to serve enduring coordination functions. Joint Action Groups are temporary elements established to address specific, short-term objectives

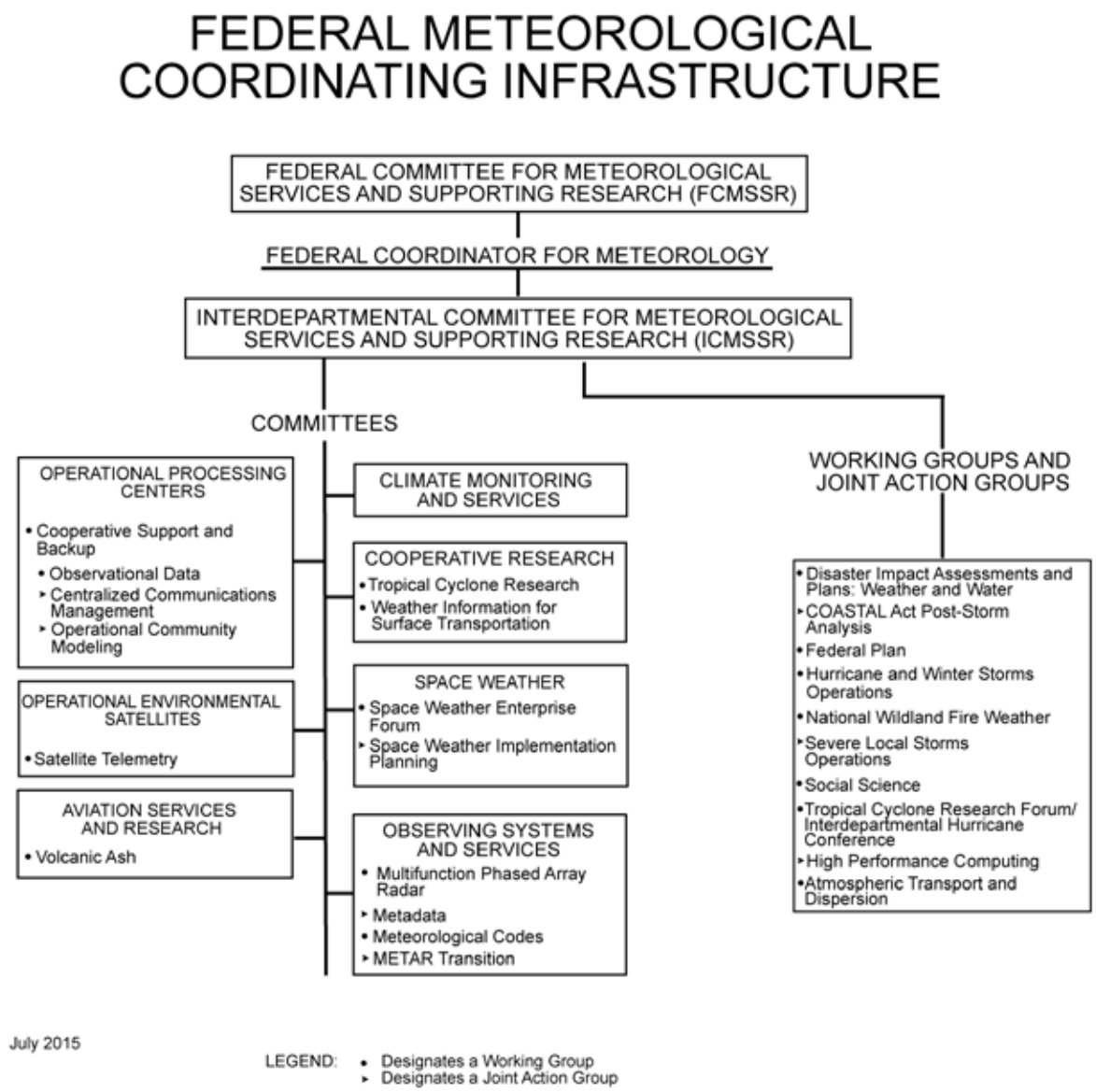

Figure 1The Federal Coordinating Infrastructure.

Using these multiagency groups, OFCM pursues the following objectives as the means to achieve 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 development and coordination of interagency plans and procedures for meteorological services and supporting research.
- 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 on 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 and integrated programs.

OFCM HIGHLIGHTS FOR FISCAL YEAR 2015 AND PLANS FOR FISCAL YEAR 2016

Federal coordination activities during FY 2015 and plans for FY 2016 are described here, organized by program/mission area and ICMSSR standing committee. The highlights begin with activities reporting directly to the Federal Coordinator, followed by the program/mission area and the ICMSSR standing committees.

Activities Reporting to the Federal Coordinator

Support for Plans and Analyses Mandated by the COASTAL Act of 2012

Congress passed the Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act in June 2012 to lower the cost of the National Flood Insurance Program by better discerning wind versus storm surge damages in cases where little tangible evidence beyond a building's foundation remains for the proper adjustment of insurance claims after a hurricane or tropical storm. This law requires NOAA to produce detailed post-storm analyses following named storms that affect the coastal zone of the United States. These analyses are to be submitted to the Federal Emergency Management Agency (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 law mandates that the database and post-storm model be operational by December 28, 2013 (540 days after enactment).

The COASTAL Act also requires that NOAA, in consultation with OFCM, provide several interim deliverables to Congress, including an assessment of current capabilities and needs to provide the required post-storm analyses. The Federal Coordinator established the Joint Action Group for the COASTAL Act Post-Storm Analysis (JAG/CAPSA) to develop a COASTAL Act Capabilities Development Plan (CACDP) in collaboration with NOAA. The plan, which was submitted to the NOAA Administrator on April 15, 2013 and released to the Department of Commerce on June 7, 2013, provides for the collection of the required observational (covered) data to support post-storm assessments.

In 2015, the JAG/CAPSA, was realigned under the Working Group for Disaster Impact Assessments and Plans: Weather and Water (WG/DIAP). The observing protocol to support collection of data for the post-storm analyses required by the COASTAL Act was published in December 2013, exercised in 2015 for Hurricane Erika, and will be included in subsequent editions of the National Plan for Disaster Impact Assessments: Weather and Water Data (Publication FCM-P33).

Programs and Mission Areas

National Aviation Weather Program

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 state-of-the-art information to aviation end users where and when they need it. OFCM also participates in a variety of Next Generation Air Transportation System (NextGen) interagency planning office activities, including the NextGen Weather Advisor meetings, NextGen Executive Weather Panel meetings, and the Research, Engineering, and Development (RE&D) initiative. OFCM coordinated with the IPO on several activities related to wind turbine radar interference, including arranging an opportunity for several agencies to participate in a briefing on a screening tool for wind turbine interference. Meanwhile, OFCM continued its participation in the Friends and Partners of Aviation Weather collaboration. OFCM staff also supported aviation-weather initiatives related to meteorological codes and observing practices under the auspices of other OFCM coordinating groups.

OFCM will continue the collaborative work within the NextGen structure in FY 2016, but will focus largely on related code and observing practice issues being addressed in other groups.

National Operational Processing Centers

In FY 2015, ICMSSR deactivated the National Operational Processing Centers Program Council (NOPC). The ICMSSR assumed all NOPC responsibilities including senior management oversight for the Committee for Operational Processing Centers (COPC) and facilitates improved collaboration among the NOPC member organizations that have direct oversight of COPC members. All NOPC principal members, NOAA National Weather Service (NWS); NOAA National Environmental Satellite, Data, and Information Service (NESDIS); the U.S. Navy Meteorology and Oceanography Command; and the U.S. Air Force Directorate of Weather are represented on the ICMSSR. The ICMSSR will set policy; provide strategic vision, planning, program guidance, and interagency funding authority; identifies future roadmap capabilities for their own agencies; determines how to effectively position themselves for future requirements and collaboration; and identify coordinated approaches to solving the Nation's highest priority environmental information needs.

National Space Weather Program

Over the past 20 years, the National Space Weather Program Council (NSWPC) has sought closer coordination of space weather science, research, and services to the Nation. In 2014, the NSWPC directed the Committee for Space Weather (CSW) to develop an implementation plan to achieve the goals described in the 2010 *National Space Weather Program Strategic Plan* and, in response, CSW established the Joint Action Group for Space Weather Implementation Planning (JAG/SWIP). The action group comprises six working groups to address the five goals of the *Strategic Plan* as well as disaster preparedness, readiness, and response. Development of the implementation plan began in April 2014, supported by more than 50 subject matter experts from all nine NSWP agencies.

NSWPC, CSW and JAG/SWIP activities were suspended in October 2014 in order for the agencies to support the OSTP Space Weather Operations, Readiness, and Mitigation (SWORM) Task Force. Activities of the NSWP will resume after the OSTP publishes the National Space Weather Strategy (NSWS) and National Space Weather Action Plan (SWAP) which was largely based the draft NSWP Implementation Plan. OFCM will collaborate with OSTP to manage the NSWP and execute space weather elements of the SWAP.

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. The MPAR Working Group, comprising various elements of the four stakeholder agencies as well as representatives from several other interested agencies, meets several times a year to review program progress. The MPAR initiative achieved several milestones this during FY 2015:

- The 10-panel demonstrator, the first S-band dual pol weather array to collect precipitation data in the environment was assembled at Lincoln Lab from the 64-element dual pol panels that have been under development and delivered to the National Severe Storms Laboratory for testing. Using a rudimentary backend designed for taking experimental data, the demonstrator is providing the first dual pol data precipitation data from an active array.
- Planning for the MPAR Advanced Technology Demonstrator (ATD) was formalized in FY 2015 and moved along rapidly, from initial planning proposal in October 2014 through a series of meetings to Preliminary Design Review in August 2105. The planning team settled on a 76 panel antenna with 24 overlapped subarrays, a backend leveraging the Navy's Affordable Common Radar Architecture, highly flexible off-the-shelf mounting pedestal to facilitate calibration, applications software architecture, and National Weather Radar Testbed facility reuse concept.
- An updated siting study that added military base air traffic control radars was completed, expanding the number of potential radar replacements to 619.

Efforts to socialize the MPAR initiative continued, with a briefing at the Johns Hopkins University Applied Physics Lab, a paper presented at the annual American Meteorological Society (AMS) meeting, and submission of a paper for a phased array radar edition of the *IEEE Proceedings*. In addition, OFCM continued to represent the interests of MPAR as NOAA Senior Steering Group representative on the interagency Wind Turbine Radar Interference Mitigation Working Group and a new effort to investigate using funding for spectrum reallocation to offset MPAR costs.

Work planned for FY 2016 includes the following:

- Continued testing of the 10-panel demonstrator and analysis of the results to provide important insights into a number of relevant issues, including sensitivity, cross-polar isolation, and antenna calibration.
- Continued planning for the ATD, including Critical Design Review in January 2016.
- Planning and conducting the MPAR Technology Progress Seminar in Washington D.C. in April 2016.
- Presentation of a paper at the Annual AMS meeting in January.
- Potential analysis of the potential for leveraging spectrum offsets.
- Continued interagency engagement in issues like wind turbine radar interference to socialize MPAR potential.

Committees, Working Groups and Joint Action Groups

Committee for Operational Processing Centers

In FY 2015, COPC continued to facilitate the exchange of information concerning numerical weather and ocean prediction modeling efforts, data resources or problems, and atmospheric, oceanographic, and satellite products for NOAA's National Centers for Environmental Prediction and Office of Satellite and Product Operations, the Air Force 557 Weather Wing, the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center and Naval Oceanographic Office. Semiannual meetings of COPC continued in FY 2015 and are expected to continue in FY 2016.

Working Group for Cooperative Support and Backup

Activities under COPC and its Working Group for Cooperative Support and Backup included:

- Exchange of JMA's Himawari-8 data for situational awareness, MTSAT replacement, and GOES-R readiness capabilities. NOAA STAR is distributing the 16 channel data to NCEP and the Navy Centers in a non-operational environment. Air Force is distributing 5 channel data via the MARK IVB and sharing that same feed with FNMOC.
- Coordination and planning data exchange using NESDIS' future enterprise data dissemination service called Product Dissemination and Access (PDA). Development of a process to support DoD's existing legacy data flow purposes and to move new data requirements to the PDA as the least disruptive approach forward.

Working Group for Observational Data

The Working Group for Observational Data (WG/OD) facilitates the acquisition, processing, and exchange of observational data among the national operational processing centers (OPCs) and other related data centers.

During FY 2015, the working group satisfied a number of interagency satellite data requests, resolved several NEXRAD radar data exchange issues, and assisted in resolving a radar mosaic gap in the Guantanamo Bay area. The Working Group continued efforts to update the Environmental Satellite Data Annex and moved forward with the initiative to develop a Conventional (surface) Data Annex which will outline the principal guidelines and procedures for conventional (surface) data acquisition, processing, and exchange.

In FY 2016, the Working Group will continue its efforts to meet interagency observational data acquisition, processing, and exchange needs including:

- Collaborative work among the national operational processing centers (OPC) to discover, report, share, and track to resolution critical metadata errors which, if unresolved, may cause a significant impact to DOD numerical models and products.
- Collaborative efforts specifically to resolve numerous upper air metadata errors resulting from the WMO directed transition from Traditional Alphanumeric Code (TAC) forms to Binary Universal Form for the Representation of meteorological information (BUFR)

- Update and maintenance of an OPC-comprehensive observational data inventory reflecting data streams used by all OPCs
- Update of the Environmental Satellite Data Annex and development of a Conventional (Surface) Data Annex to the Memorandum of Understanding for Data Acquisition, Processing, and Exchange
- New satellite data and ocean data sources and products
- Incorporation of the Space Weather data sector into working group activities

Joint Action Group for Centralized Communications Management

The Joint Action Group for Centralized Communications Management worked to create a second data exchange point between NOAA and DOD in Boulder, Colorado.

Committee for Operational Environmental Satellites

Responding to stakeholder desire to improve interagency communication and coordination of matters regarding the use environmental satellites the Committee for Operational Environmental Satellites (COES) was re-established in 2014. COES helps advance interagency goals better coordination of operational environmental satellite systems planning.

COES conducted five meetings in FY2015 to address its stated goals. It continued to assess the need for interagency satellite requirements and conducted a systematic review of satellite capabilities available to the operational weather community. It provided an advocacy letter to NOAA on the interagency need for operational geosynchronous environmental satellite coverage of the Indian Ocean which supported the US delegation to the annual Coordinating Group for Meteorological Satellites (CGMS) of the World Meteorological Organization. COES also consolidated interagency need statements to support NOAA continuation of the Joint Polar Satellite System near-constant crosstrack night visual imaging capability.

Finally, COES and OFCM organized, led, and provided speakers a session dedicated to federal agency and commercial use of NOAA satellite systems at the NOAA Satellite Conference.

Working Group for Hurricane and Winter Storms Operations and Research and the Interdepartmental Hurricane Conference

In FY 2015, the Working Group for Hurricane and Winter Storms Operations and Research (WG/HWSOR) continued to manage the interagency operations plans for hurricanes and winter storms and address related issues relevant to the Federal meteorological community.

The National Hurricane Operations Plan (NHOP) describes individual agency responsibilities and prescribes operational procedures, common reference points, formats for data exchange, tropical cyclone names and pronunciations, and other information to achieve economy and efficiency in the provision of tropical cyclone forecasting and warning services to the Nation. The plan is reviewed and updated annually in advance of the hurricane season to address action items and implement agreements reached at the Interdepartmental Hurricane Conference (IHC). The working group published the 53nd edition of the NHOP in FY 2015, including updated guidance on notification procedures among the tropical cyclone forecasting centers, DOD

weather reconnaissance support to NOAA, tropical cyclone names and pronunciations, data codes, and air traffic control-related procedures.

WG/HWSOR also manages the National Winter Storms Operations Plan (NWSOP) to coordinate the activities of the federal agencies providing enhanced observations of severe winter storms that affect the coastal regions of the United States. The plan focuses on the coordination of requirements for DOD and NOAA aircraft reconnaissance observations with the goal of improving the accuracy and timeliness of winter storm forecasts and warning services. The current NWSOP was published prior to the 2012-2013 winter season and minor changes for the 2013-2014 winter season were not deemed significant enough to warrant an early update to the plan. A new edition of the plan will be published in FY 2016.

The WG/HWSOR depends on the annual IHC to meet its hurricane-related responsibilities. The following paragraphs summarize the FY 2015 IHC and Tropical Cyclone Research Forum.

OFCM hosts the IHC each year to provide a forum for the responsible federal agencies, together with representatives from the academic community, industry, and other user communities such as emergency management, to prepare for the upcoming hurricane season and make improvements to the Nation's hurricane forecasting and warning program. OFCM develops the agenda with input from WG/HWSOR and the Working Group for Tropical Cyclone Research (WG/TCR).

OFCM hosted the 69th Interdepartmental Hurricane Conference and Tropical Cyclone Research Forum March 2-5, 2015, in a combination face-to-face and online, virtual conference. The primary face-to-face locations were the Jacksonville, Florida, and the National Hurricane Center in Miami, Florida. The distribution of attendees included 83 in-person and 60 virtual attendees representing six federal agencies as well as academia, private industry, and the media.

The theme was “Tropical Cyclone Operations and Research: Setting our Future Course.” The IHC and forum sessions included the following topics:

- Review of the 2014 Tropical Cyclone Season.
- Research Priorities of the Operational Centers.
- Transitioning Research to Operations
- Observations and Observing Strategies
- Advances in Tropical Cyclone Model Development and Evaluation
- Tropical Cyclone Plan Mid-Course Assessment—Operational Needs and Research Priorities
- Future of the IHC
- Products, Services, and Societal Impact

The action items developed at the conference are listed below:

- The OFCM will post forum presentations and this summary on the conference web page. (Complete)
- The OFCM will publish the annual National Hurricane Operations Plan (NHOP), to include changes recommended to and accepted by the WG/HWSOR, no later than May 1, 2015. (Complete)
- The OFCM will work with NOAA and the Navy to secure the funding and support for the Automated Tropical Cyclone Forecast (ATCF) system.

- Through the OFCM infrastructure, a strategic plan for improved tropical cyclone reconnaissance and surveillance systems and observations (manned, unmanned, space-based, etc.) will be developed.
- OFCM will complete and publish a mid-course assessment, to be conducted by the WG/TCR, on the Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead (FCM-P36-2007).

Working Group for Disaster Impact Assessments and Plans: Weather and Water Data

Disaster-relevant data acquired from many routine observing systems often do not provide data coverage and density sufficient to adequately document the effects of a major storm or flood or enable understanding of small-scale, localized weather and water processes. As a result, routine observations are supplemented by mobile observing system data and post-storm analysis of impact features, such as high water marks and wind damage, to fill information gaps and obtain more complete spatial coverage. Collecting this information contributes to determination of the intensity and magnitude of storms and may support Presidential disaster declarations. The information may also be used in a number of other ways: to assess threat potential; validate emergency management and hurricane storm surge models; update FEMA flood insurance rate maps; assist in evaluating indeterminate loss causes; and improve forecasting models. Furthermore, the National Institute of Standards and Technology and various state agencies use the data to improve building codes and construction practices.

To improve the efficiency of data collection 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. The WG/DIAP published the National Plan for Disaster Impact Assessments: Weather and Water Data (NPDIA) in October 2010. The 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.

In response to the COASTAL Act of 2012 requirement to establish a protocol for data collection for post-storm assessments, the WG/DIAP developed a COASTAL Act Data Protocol Annex to the NPDIA. This annex outlines the interagency protocol for responding to storms that could come under provisions of the COASTAL Act of 2012. It describes the plan for capturing the necessary data and assembling it in NOAA's Coastal Weather and Water Event Database (CWWED) for assimilation into NOAA's Named Storm Event Model (NSEM). It also specifies how these data are made available to FEMA, other federal, state, and local government agencies, private insurance adjusters, and the general public to help evaluate indeterminate loss causes and insurance coverage responsibilities. The next revision of the NPDIA will include the new COASTAL Act data protocol.

Other upcoming changes to the NPDIA include the latest data collection protocol for response to tsunamis and the revised Enhanced Fujita (tornado) Scale now under development. OFCM is supporting the Enhanced Fujita Scale revision effort, participating in the main American Society of Civil Engineers committee and sub committees on radar, remote sensing, and in situ observations.

Aerial support from the Civil Air Patrol provides one of the sources of pre-event and post-event data to support impact assessments. Under the OFCM-coordinated Air Force-NOAA Memorandum of Agreement for Civil Air Patrol support, in FY 2016 OFCM will continue to coordinate post-storm data acquisition surveys in response to natural disasters and agency requirements. The annual agreement between OFCM and the U.S. Air Force for reimbursable support funds Civil Air Patrol missions such as Alaska glacial lake damming assessments, tornado damage photos and video, and severe flooding imagery.

Working Group for Volcanic Ash

The Working Group for Volcanic Ash (WG/VA) lays the groundwork for National volcanic ash policy and coordinates cooperative interagency efforts regarding volcanic ash products, services, procedures, and research, and oversees national volcanic ash operations for aviation in support of the ICAO International Airways Volcano Watch.

In FY 2016, the Working Group will continue new initiatives to revise the National Volcanic Ash Operations Plan for Aviation (NVAOPA) and the proposed North American Volcanic Ash Contingency Plan for Aviation. The NVAOPA revision will include the new structure of the Air Force weather function.

Atmospheric Transport and Dispersion (ATD)

On June 9, 2015, OFCM sponsored a special session of the 19th annual George Mason University Atmospheric Transport and Dispersion Modeling Conference. The theme of the session was *Observations and Modeling of Aerosols and Tracers: Potential Impacts for Two Governmental Programs*. Subject matter experts from DOC/NOAA (National Weather Service Headquarters, National Weather Service/National Centers for Environmental Prediction, Office of Oceanic and Atmospheric Research/Air Resources Laboratory (ARL), and National Environmental Satellite, Data, and Information Service), Nuclear Regulatory Commission, NASA (Goddard Space Flight Center and Syneren Technologies Corporation), the US Navy, and the US Forest Service made presentations and answered questions during this session.

The session highlighted the implications of agency ATD modeling and observations on two main government ATD related programs: the Joint Polar Satellite System (JPSS), and the Next Generation Global Prediction System (NGGPS). However, planners took advantage of the broad expertise and experience of the presenters to provide a more diverse view of Federal activities in the ADT arena that went beyond JPSS and NGGPS advancements. OFCM will continue its partnership with GMU by sponsoring a session in the 2016 conference, which will be held at GMU in June.

Committee for Observing Systems and Serivces

In FY 2015 much of the OFCM work related to the Committee on Observing Systems and Services (formerly the Committee for Integrated Observing Systems (CIOS)) focused on collaboration with the American Meteorology Society (AMS) Nationwide Network of Networks Committee to investigate jointly sponsoring a forum on "Observing the Environment from the Ground Up" Discusses led to the decision to plan the forum for March 8-9, 2016 at the American Association for the Advancement of Science in Washington, DC.

Other activities related to observing involved updates to Federal Meteorological Handbooks (FMHs).

- Work continued on a variety of issues related to surface observing and FMH-1, Surface Weather Observations and Reports. An update to the handbook has been delayed pending the resolution of some of the observing issues within the participating agencies. The publication of a change is anticipated in 2016.
- A new change to FMH-11,Doppler Radar Meteorological Observations (WSR-88D) Part A - System Concepts, Responsibilities, and Procedures was completed by the NWS Radar Operations Center (ROC) and forwarded to OFCM for coordination and publication. After several rounds of staff coordination and further modifications, a final version of the change was complete and prepared for approval by ICMSSR. During FY 2015 the approval process will be completed and the new version will be published. Meanwhile, the ROC has also provided an update to Part C - WSR-88D Products and Algorithms, which is under review and will also be published in FY 2016.

Joint Action Group for Unmanned Aerial Systems

OFCM aligned Joint Action Group for Unmanned Aerial Systems (UAS) for Environmental Monitoring (JAG/UAS-EM) activities with other groups working UAS development and utilization issues including the Interagency Coordinating Committee for Airborne Geosciences Research and Applications (ICCAGRA) and the NSTC Subcommittee for Unmanned Systems.

The ICCAGRA meets semiannually to improve cooperation, foster awareness, facilitate communication among airborne instrument-sponsoring agencies, and serve as a resource to senior-level management on airborne geosciences issues. The Committee facilitates cooperation on the use of airborne platforms and payloads for individual investigators as well as national and international field campaigns. OFCM supports ICCAGRA through meeting participation and access to the OFCM federal meteorological coordinating infrastructure.

OFCM continues to support the activities of the CENRS Ocean Science and Technology Subcommittee's work on unmanned systems. OFCM's participation provides a connection to meteorological research and service providers and supports effective coordination of unmanned system applications across the federal enterprise.

Committee for Cooperative Research

Working Group for Tropical Cyclone Research

For additional information on tropical cyclone research, see the Working Group for Hurricane and Winter Storms Operations and Research and Interdepartmental Hurricane Conference section above.

In 2007, the Joint Action Group for Tropical Cyclone Research (JAG/TCR) completed the Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead. This plan presented a shared set of R&D priorities matched to operational requirements from the tropical cyclone forecast and warning centers and served as a baseline for NOAA's Hurricane Forecast Improvement Program (HFIP). In 2008, 2010, and 2012 the Working Group for Tropical

Cyclone Research (WG/TCR), which succeeded the JAG/TCR for continuity, assessed agency research activities mapped against tropical cyclone research needs and operational priorities. The assessments have enabled WG/TCR to establish a successful process to accomplish the following tasks:

- Update the operational priorities.
- Evaluate how research is contributing to meeting operational priorities.
- Support informed research manager decisions on future investments.
- Facilitate interagency collaboration and coordination.

During the 2015 Interdepartmental Hurricane Conference (see above under Working Group for Hurricane and Winter Storms Operations and Research and the Interdepartmental Hurricane Conference) the WG/TCR co-chairs led a panel of the tropical cyclone forecast center directors in a discussion of changes implemented as a result of tropical cyclone research conducted since 2007 and of on-going research priorities. The results of this discussion serve as a starting point for an assessment of the effectiveness of the 2007 plan. Resource constraints have impacted the WG's development of a mid-course assessment. Instead, a final assessment is being considered and will likely be discussed at the 2016 IHC.

Working Group for Weather Information for Surface Transportation

In FY 2015, OFCM continued to stay engaged with the surface transportation community, participating in the AMS Intelligent Transportation Systems/Surface Transportation Weather Committee, including the face-to-face meeting at the AMS annual meeting. In addition, OFCM worked with the National Academy of Sciences Transportation Research Board (TRB), peer reviewing papers for the 2016 TRB Annual Meeting.

Working Group for Meteorological Codes

In FY 2014, OFCM formed the Joint Action Group for IWXXM Implementation (METAR Transition) in response to the International Civil Aviation Organization (ICAO) initiative to transition the METAR family of codes (METAR, SPECI, TAF, and SIGMET) from the current traditional alphanumeric code (TAC) format to an Extensible Markup Language (XML)-based code called IWXXM-US. In 2015 the JAG began the process of addressing governance issues, which related closely to OFCM responsibilities for coordinating and documenting interagency agreements on observing practices and codes. In FY 2016 the JAG will develop a plan for transitioning the TAC format to IWXXM-US.

In addition, some of the expected revisions of Federal Meteorological Handbook No. 1, Surface Weather Observations and Reports described above (see the Committee for Observing Systems and Services ection above) will involve coding practices, which fall under the purview of the Working Group for Meteorological Codes.

OFCM External Coordination

Executive Office of the President (EOP)

Office of Management and Budget (OMB)

OFCM reinvigorated dialog with OMB regarding the interagency coordination process and the requirement for a cross-agency budgetary view to the meteorological enterprise. The Federal Coordinator established new working relationships with the OMB program analysts for the agencies engaged in the meteorological enterprise. In 2016, work will begin to update the OFCM foundational documents similar to OMB Circular A-62.

Office of Science and Technology Policy (OSTP)

OFCM supported the Space Weather Operations, Readiness, and Mitigation (SWORM) task Force by providing all materials from the ongoing NSWP Space Weather Implementation Plan activity and suspending other NSWP activities to allow maximum participation in this Presidentially-directed initiative. OFCM is working closely with OSTP to prepare for follow-on activities related to the Space Weather Action Plan due for release in late 2015.

OFCM also participates in the US Group for Earth Observations (USGEO) managed through OSTP. In 2015, OFCM participated in the USGEO Satellite Framework Task Force to develop a strategy to more leverage current and planned environmental satellite investments across the whole of the Federal government.

Additionally, OFCM supports interagency coordination efforts through the Subcommittee for Unmanned Systems (SUS), the Subcommittee for Disaster Reduction (SDR), and other elements of the National Science and Technology Council (NSTC) Committee for Environment, natural resources sustainability (CENRS).

NAS/NRC Board on Atmospheric Sciences and Climate

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

NAS/NRC Space Science Board, Committee on Space and Solar Physics

The NSWP Executive Secretary provided program updates to the NRC Space Science Board (SSB) and its Committee on Space and Solar Physics (CSSP). The OFCM anticipates that the CSSP will continue to invite the NSWP members and the Executive Secretary to participate in its semiannual meetings. The OFCM and SSB are seeking ways to leverage each other's strengths in bringing together the federal and nongovernmental space weather communities.

American Meteorological Society

OFCM supports AMS activities by participating in AMS conferences and workshops and serves on committees, groups, and teams as appropriate. In FY 2015, OFCM co-authored and/or presented two papers at the 95th AMS Annual Meeting and will present two papers at the 96th

Annual meeting in 2016. In addition, OFCM is co-sponsoring a forum in March 2016 with the AMS Nationwide Network of Networks Committee (see section on Committee for Observing Systems and Services above).

FY 2015 OFCM PUBLICATIONS

The publications listed in the table below were prepared in hard copy and/or were added to OFCM's website (www.ofcm.gov) during FY 2015.

OFCM PUBLICATION	DATE	NUMBER
PLANS (P)		
Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 2015	October 2014	FCM-P1-2014
National Hurricane Operations Plan • 2015 Build 16.0 Dual Pol WSR-88D Tropical Cyclone Operations Plan (05/15/2015) ◦"QUICK CHECK" List • 2015 Build 15.0 Dual Pol WSR-88D Tropical Cyclone Operations Plan (05/15/2015) ◦"QUICK CHECK" List	May 2015	FCM-P12-2015
PROCEEDINGS		
2015 Tropical Cyclone Research Forum/69th Interdepartmental Hurricane Conference Summary Report		March 2015
Proceedings of the Special Session, 19th Annual George Mason University (GMU) Atmospheric Transport and Dispersion Modeling Conference		June 2015

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, weather, ocean, aviation and space 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), the National Centers for Environmental Prediction (NCEP), and the National Water Center (NWC). 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 forecasts, watches, warnings and advisories for hazardous winter weather conditions, high wind events, dense fog, river levels, flooding and extreme temperatures.

The NWS uses surveillance 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 weather observing systems at airports, and weather balloons to obtain vertical measurements of the atmosphere. Some observations are obtained through the Cooperative Observer Program (COOP), 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, aviation and space weather forecast guidance that is available to users. The NWS' highly trained and skilled workforce uses powerful workstations to analyze 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 integrated dissemination infrastructure includes NWR and satellite broadcasts, while the internet rapidly distributes this information.

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.

Figure 1: The Advanced Weather Interactive Processing System (AWIPS) is a technologically advanced information processing, display, and telecommunications system. AWIPS is an interactive computer system that integrates all meteorological and hydrological data, and timely forecasts and warnings (NOAA Image)

RFCs routinely generate short range (deterministic) through extended range (probabilistic) river forecasts and (deterministic) flash flood guidance. Information from the RFCs and NCEP's Weather Prediction Center (WPC) serves as the basis for local flood and flash flood warnings, watches and advisories issued by the WFOs. 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. A new element of the NWS water resources program infrastructure, NWC, was completed in early 2014 on the campus of the University of Alabama in Tuscaloosa, Alabama. The NWC will serve as a cornerstone for collaboration among Federal water agencies and provide a central hub to integrate and advance regional field operations and services. Initial Operating Capability was attained in May 2015. The NWC provides comprehensive snow observations, analyses, data sets and map products for the Nation. NWC 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. The capabilities of NWS Water Resources Services were recently expanded through the implementation of the Community Hydrologic Prediction System (CHPS) at the 13 NWS RFCs. CHPS is the RFC operational framework, allowing for broad systems interoperability to support new water resources-related forecasts.

NCEP consists of nine national centers that provide a backbone of national expertise for both forecast and numerical guidance. The NCEP Storm Prediction Center (SPC) provides forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. The National Hurricane Center (NHC) provides forecasts of tropical weather systems and issues watches and warnings for the U.S. and surrounding areas for systems in the tropical North Atlantic, Caribbean, Gulf of Mexico and Eastern Pacific and provides educational outreach and guidance for the international community in the region. The Central Pacific Hurricane Center (Honolulu) and the Joint Typhoon Warning Center (Guam) provide additional tropical cyclone coverage for the central and western Pacific, though not part of NCEP. The WPC provides analyses and forecast products with a focus on precipitation amount and type, winter

precipitation, model diagnostics, surface pressure, frontal analysis and forecast products for the medium range (days 3-7). The Ocean Prediction Center (OPC), along with 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 assessments and forecasts of the impact of short-term climate variability, emphasizing enhanced risks of weather-related extreme events for use in mitigating losses and maximizing economic gain. The Space Weather Prediction Center (SWPC) provides real-time monitoring and forecasting of solar and geophysical events which impact satellites, power grids, communications, navigation, and many other technological systems. The Environmental Modeling Center (EMC) develops and improves numerical weather, climate, hydrological and ocean prediction through applied research in data analysis, modeling and product development. NCEP Central Operations (NCO) sustains and executes the operational suite of numerical environmental analysis and forecast models and prepares NCEP products for dissemination. They also process and manage the flow of data and products to and from the NCEP centers, partners, and customers. NCO also operates the NWS Telecommunications Operations Center, which provides for central, continuous acquisition, communications and dissemination of NWS and other domestic and foreign hydrometeorological data and products.

There are other specialized service centers within the NWS. The Pacific Tsunami Warning Center (PTWC) and the National Tsunami Warning Center (NTWC) use data from a worldwide seismic network and Deep-ocean Assessment and Reporting of Tsunamis (DART) 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.) The Radar Operations Center (ROC) provides centralized meteorological, software, maintenance, and engineering support for all Next-Generation Radar (NEXRAD systems for NWS, Department of Defense (DOD), and Department of Transportation (DOT). The National Reconditioning Center and National Logistics Support Center (NRC/NLSC) is the hub that provides mission critical components through which NWS equipment and DOT and DOD equipment pass for repair, quality inspection, warehousing, and distribution

NWS support several health-related programs such as Heat Health, the Ultraviolet Index and Air Quality. 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.

NWS' suite of products and services enable core partners' decisions when weather, water, or climate has a direct impact on the protection of lives and livelihoods. As NWS works to fulfill the vision of a Weather-Ready Nation (WRN) its diverse portfolio of service capabilities will become more focused on a framework approach that will enable the agency to provide the foundational information and Impact-Based Decision Support Services (IDSS) needed. It is at this juncture where NWS' highly skilled workforce provides significant value to achieve its mission. IDSS is a foundational concept of NWS' WRN. Rather than developing and

transmitting a suite of products at fixed times during the day and expecting stakeholders to fully understand and take appropriate action; IDSS changes the paradigm so information users drive the update frequency and value-added meaning of the product. IDSS also provides greater flexibility for forecasters to work with key governmental partners and even embed within their emergency operations centers to give first hand support to enhance decision making and public safety.

In 2015, NOAA completed a restructure of the NWS budget to simplify and align with functions. This restructure has restored budget credibility and transparency by strengthening internal controls and customer service while improving coordination and collaboration among activities that serve NWS' overall mission. Guided by the recent National Academy of Sciences, "Becoming Second to None," and the National Academy of Public Administration (NAPA), "Forecast for the Future: Assuring the Capacity of the NWS" reports, NWS implemented the new portfolio-based budget structure and reorganized headquarters in order to better support mission operations; improve prioritization and management of resources; and improve consistency of NWS products and services.

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 continuous observations of 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.

Currently, NOAA's main satellite constellations are the 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). NOAA also operates the Suomi National Polar Partnership (S-NPP) satellite, a NOAA-NASA mission which is the precursor to the future NOAA Joint Polar Satellite System (JPSS). S-NPP became NOAA's primary afternoon orbit satellite on May 1, 2014. 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. NOAA also operates Jason-2, a joint U.S.-European specialized polar-orbiting satellite that measures ocean surface topography. In addition, on behalf of the Department of Commerce (DOC), NESDIS licenses the operation of commercial remote-sensing land-imaging satellites. NESDIS also provides long-term stewardship of environmental data, managing the world's largest collection of climatic, geophysical, and oceanographic data derived from both in situ and space-based systems.

Polar-orbiting Operational Environmental Satellites (POES)

POES circle Earth in a nearly north-south orbit at an altitude of 517 miles, passing close to both poles. These satellites ensure observational data for any region of 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. In addition to S-NPP, NESDIS operates

NOAA-15, NOAA-18, and NOAA-19, which continue to transmit data as back-up and secondary satellites. NESDIS also manages the command, control, and communications functions of DoD's DMSP. MetOp-B, operated by EUMETSAT and launched in 2012, provides operational environmental monitoring in the mid-morning orbit. MetOp-A provides secondary coverage. The MetOp satellites carry three instruments provided by NOAA.

In addition, NOAA operates Jason-2. 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 other measurements. This mission, also called the Ocean Surface Topography Mission, 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 U.S. civil polar-orbiting satellites, with the first launch scheduled for FY 2017, following S-NPP as the bridge mission between POES and JPSS.

Because weather forecasters rely on data from NOAA's current on-orbit assets, JPSS platforms focus on ensuring short- and long-term continuity in crucial weather forecasting, environmental monitoring, and climate monitoring data. S-NPP was successfully launched from Vandenberg Air Force Base, California, on October 28, 2011. In addition to serving as a prototype for the next-generation of NOAA's polar-orbiting satellites, S-NPP provides continuity for NASA's Earth Observing System mission. In 2013, operation was transferred to NOAA's Office of Satellite Product Operations (OSPO), and in 2014 it was declared NOAA's primary operational polar-orbiting spacecraft for NOAA's operational weather forecasting mission. JPSS-1 is scheduled to be launched no later than the second quarter of FY 2017; JPSS continues to enhance the ground segment of the program to support S-NPP operations as well as to prepare for JPSS-1. NOAA-NESDIS maintains a strong partnership with EUMETSAT, which will continue to be a cornerstone of a joint polar-orbiting constellation and will ensure NOAA-NESDIS' ability to provide continuous measurements. In FY 2015, JPSS expects to have the JPSS-2 instruments on contract and the JPSS-2 spacecraft contract awarded. JPSS-2 is planned for launch in FY 2021.

Geostationary Operational Environmental Satellites (GOES)

GOES spacecraft orbit Earth in a geostationary position at an altitude of 22,300 miles, which means they orbit the equatorial plane of Earth at a speed matching 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 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. The current constellation consists of GOES-15 (West), GOES-13 (East), and GOES-14 (on-orbit spare).

GOES Series R

Figure 2: Geostationary Operational Environment Satellite–R Series (GOES-R). Image courtesy GOES-R Series Program and Lockheed Martin Space Systems Company

Geostationary satellites remain the weather sentinels for NOAA—tracking hurricanes, severe storms, clouds, and ocean features. The next-generation geostationary satellite series is called the Geostationary Operational Environment Satellite – R (GOES-R) series. 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 Earth nearly five times faster, with more than three times the spectral coverage and four times the spatial resolution of the current GOES imager. The GOES-R series will provide users like meteorologists and government agencies with approximately 60 times the amount of data currently provided. The Geostationary Lightning Mapper (GLM), in geostationary orbit for the first time, 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 and 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 that will be available from the GOES-R series. Examples of the advanced products include improvements on: volcanic ash detection, lightning detection, dust and aerosol detection, synthetic cloud and moisture imagery, as well as one-minute interval rapid scan 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.

The GOES-R series is a collaborative development and acquisition effort between NOAA and NASA. In FY 2016, the GOES-R Series Program is planning for the completion of the GOES-R

spacecraft, ground system, flight-to-ground testing, and launch service activities to meet a launch readiness date in March 2016. Additional FY 2016 activities include delivery of the GOES-S suite of instruments, completion of the fabrication of the GOES-S spacecraft hardware, and continued development of the instruments for GOES-T.

NOAA/NESDIS Data Centers

National Centers for Environmental Information (NCEI)

The National Centers for Environmental Information (NCEI, www.ncei.noaa.gov) is the official source for historical and near-real-time data and information covering weather, climate, coasts, oceans, geophysics, and space weather.

Access to reliable and accurate long-term records of environmental data and information is critical to satisfying the Nation's wide range of business, education, and government needs related to national security, the economy, the environment, and public safety. This includes policies and decisions that have an impact on water and energy management, manufacturing, transportation, food production, public health, and many other socio-economic issues that depend on quality data records and information.

The NCEI headquarters are in Asheville, NC, with major presences also in Boulder, CO, Silver Spring, MD, and Stennis Space Center, MS. NCEI is divided into two science centers and a data stewardship division, which provides data preservation and access services.

- NCEI ensures the scientific integrity and usefulness of NCEI products and services through data synthesis, including description, monitoring, modeling, and assessment, data and information preservation, and dissemination.
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- NCEI performs quality assurance and reanalysis of historical data, including long-term satellite data records, to establish and update baseline data sets for global and national standards and environmental monitoring using current information technologies.
- NCEI's authoritative data and information enables today's events to be put in historical perspective and allows national decision-makers to make confident, data- and information-driven determinations about trends and extremes, such as how unusual or extreme a drought, snowstorm, or other environmental event is, providing for more appropriate and cost-effective emergency appropriations.
- NCEI products include decadal, annual, monthly, weekly, and daily U.S. and global weather summaries and climate reports, assessments of billion-dollar disasters, the World Ocean Atlas, and the World Magnetic Model.
- NCEI works with many partners across the Nation, including other NOAA Line Offices and Cooperative Institutes (CIs), federal agencies, and national and international contributors and users of NCEI data, including industry, academia, and government.

Center for Weather and Climate (also see Climate Services)

Previously NOAA's National Climatic Data Center, this center is responsible for preserving, monitoring, and assessing the Nation's treasure of climate and historical weather data and information.

Center for Coasts, Oceans, and Geophysics (also see Climate Services)

Previously NOAA's National Coastal Data Development Center, National Oceanographic Data Center, and National Geophysical Data Center, this center is responsible for preserving, monitoring, and assessing the Nation's treasure of coastal, geophysical, and oceanographic data and information.

The Center for Coasts, Oceans, and Geophysics (CCOG) is the trusted authority that advances and enables environmental science and related decision-making from resilient coastal communities to space weather. With oceanographic, geophysical, and solar observations that stretch from the surface of the sun to the depths of the oceans, CCOG derives products, develops assessments, and delivers information services in support of customer requirements. CCOG's capabilities support essential services to foster sustainable economic development and support coastal communities to prepare for and respond to emergencies. CCOG conducts integrated scientific analyses of coastal and marine environmental data sets to better understand historical trends, anomalies, and the frequency of occurrences of events in large marine ecosystems over a decadal or longer temporal scale. In support of the National Snow and Ice Data Center, CCOG delivers sea ice extent and concentration products supporting NOAA and Navy operational ice forecasts in the Arctic as well as climatological sea ice trends. These long-term environmental and marine climatology data records provide NOAA, national and international data centers, researchers, and coastal zone managers information to understand an ecosystem's historical record and to better enable the decision-making process, to establish status and trends, and to forecast future impacts on the ecosystem. CCOG is a leader in integrating physical, biological, chemical, and living coastal and marine resource data based on the user requirements for this purpose. In addition, CCOG promotes the scientific integrity and usefulness of its products and services through interactions with data providers, users, and the public.

- NCEI's **Coastal Data Development** (CDD) program, based in Stennis, MS, conducts integrated scientific analysis of coastal and marine environmental data sets to better understand historical trends, anomalies, and the frequency of occurrences of events in large marine ecosystems. CDD focuses on the development of products and services that bring together scientists and coastal managers in support of coastal ecological and observational data and information.

Data Stewardship Division

The Data Stewardship Division (DSD) of NCEI provides data preservation and access services that enable the NCEI centers, other government agencies, and the public to exploit NOAA's multi-billion dollar investment in environmental observations. DSD maintains the nation's archive of environmental information, as well as international data holdings through the World Data System. It maximizes availability of archived information by leveraging data portals such as data.gov and the World Meteorological Organization Information System. DSD leads and

participates in developing and implementing standard practices in data and information management that facilitate data services and interoperability. DSD's archive and access capabilities make use of a cost-effective suite of systems including CLASS, the Comprehensive Large Array-data Stewardship System, which supports satellite operations.

To guarantee the integrity and utility of NCEI's physical and digital holdings, DSD performs essential data management functions including:

- Acquisition of real-time and historical data sets from national and international sources;
- Automated data ingest, including quality assurance, quality control, and data validation;
- Data rescue from limited access sources or deteriorating media;
- Secure preservation, including redundant offsite storage and media migration;
- Interoperable data sharing through use of national and international standards for metadata, data formats, and web services;
- Data documentation and metadata cataloging;
- Information processing, product generation and data reprocessing; and
- Data publication and dissemination.

NOAA Central and Regional Libraries

The NOAA Central Library, under the auspices of NCEI, is located in Silver Spring, MD, with satellite libraries in Miami, FL, and Seattle, WA. The library provides information and research support to NOAA staff and the public. The library also networks with over 30 NOAA libraries across the nation. Disciplines covered in the library's holdings include weather and atmospheric sciences, oceanography, ocean engineering, nautical charting, marine ecology, marine resources, ecosystems, coastal studies, aeronomy, geodesy, cartography, mathematics, and statistics. See www.lib.noaa.gov for more information.

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 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.

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. Prior to the start of the 2014 Hurricane season, NOAA Aircraft Operations Center, working with the Mexican Navy, Air Force, CONAGUA, the National Hurricane Center (NHC), and the U.S. Embassy, established an agreement that would allow NOAA Hurricane Hunter aircraft to base out of Mexican Navy and Air Force facilities for hurricane reconnaissance tasking for eastern Pacific storms. In October, 2014, N43RF successfully completed a detachment to La Paz, Mexico, in support of NHC tasked missions on Hurricane Simon. This relationship allows NHC to further investigate these storms and provide watches and warnings for eastern Pacific hurricanes.

National Aeronautics and Space Administration Basic Meteorological Services

The National Aeronautics and Space Administration (NASA) is a long-term partner with the National Oceanic and Atmospheric Administration (NOAA) for building and launching the U.S. Polar Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellite (GOES), civilian weather satellites, under reimbursable arrangements. Additionally, after the termination of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Program, NASA took on the role of the acquisition agency for the NOAA-funded *Joint Polar Satellite System* (JPSS) Program. Several missions, including the Ocean Surface Topography Mission (OSTM) and Suomi National Polar-orbiting Partnership (Suomi NPP), are NASA research missions that were developed in partnership with NOAA and are now being operated by NOAA as part of the operational weather system. Jason 3, which is under development by NOAA, is a follow-on to the TOPEX/Poseidon, Jason-1, OSTM series. In the President's FY 2015 budget request, NASA assumed responsibility for the sustained climate measurements such as total solar irradiance, vertical ozone profiles and Earth's radiation budget in the JPSS-2 (2021) timeframe. Additionally, the President's FY 2016 budget request transfers responsibility from NOAA to NASA for the completion and launch of the TSIS-1 instrument to the ISS, as well as the development and operation of the next mission in the ocean altimetry series, Jason CS.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

Interagency Collaborative Research Programs and Projects

The National Earth System Prediction Capability

The National Earth System Prediction Capability (ESPC) is an ongoing collaborative project among the National Oceanic and Atmospheric Administration (NOAA), U.S. Navy, U.S. Air Force, Dept. of Energy (DOE), National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF).

The National ESPC program will provide a more accurate global ocean and atmospheric forecast system with longer skillful forecast times at synoptic, sub-seasonal, seasonal, and inter-annual 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 current modeling approaches. Additionally, it will continue to develop a national common modeling architecture to improve cross-agency collaboration, emphasizing more efficient

computational architectures to allow real-time high-resolution operational prediction at these extended time scales. In FY 2016, predictability demonstration plans will be refined, and science workshops and early benchmark testing will be conducted. The immediate program goal is to advance skillful forecasts (relative to climatology) from the operational capability, currently 7-10 days, to 30 days and subseasonal. Follow-on program goals include coordinated interagency predictions and projections at the subdecadal and decadal time scales. Additional information can be found at: www.espc.oar.noaa.gov.

Joint Center for Satellite Data Assimilation

The Joint Center for Satellite Data Assimilation (JCSDA) is a USA 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 environmental analyses and forecast models. The JCSDA is a collaborative effort that allows the development and testing of techniques 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.

Figure 3: The 300-MW Stateline Wind Energy Center located on VanSycle Ridge between the states of Washington and Oregon in the WFIP 2 study domain. Photo Courtesy of Pacific Northwest National Lab.

The JCSDA has the following goals: (1) Reduce the average time for operational implementation of data from new satellite sensors to less than one year, (2) Increase the use and impact of current satellite data in numerical weather prediction models, (3) Advance common data assimilation infrastructure and methods, and (4) Assess the impacts of data from advanced satellite sensors on environmental predictions. By meeting these goals, the JCSDA achieves its objective of maximizing the nation's return on its investment in global observing systems and modeling, and providing improvements to the U.S. forecasting system (civilian and military), which in turn contributes to protecting citizens lives and property and the nation's global interests. Priorities for the JCSDA in FY16 include successful exploitation of new research (GPM, SMAP, Rapidscat, CYGNSS, etc.) and operational (GOES-R and JPSS) satellites, improving the use of cloud-affected satellite data and Atmospheric Wind Vector observations, and expanding a standing observation system impact assessment capability.

Wind Forecast Improvement Projects (WFIP 1 and WFIP 2)

WFIP 1 was a success for developing public-private partnerships towards a common end goal – resolving a scientific challenge. For WFIP 1, wind energy companies shared meteorological observations collected on tall towers and wind turbines on wind farms with NOAA, who used the data for model verification and validation, as well as assimilation into its advanced, rapidly refreshed weather models. NOAA and DOE have encouraged 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.

DOE and NOAA will build on these efforts through a new effort, the Wind Forecasting Improvement Project in Complex Terrain (WFIP 2), which will develop further improvements to foundational atmospheric model physics in predicting wind ramp and day-ahead events for areas of complex terrain. WFIP 2 is a multi-year DOE and NOAA sponsored project done in conjunction with four DOE National Laboratories and FOA awardee Vaisala, Inc. WFIP 2 will focus on improving the physical understanding of atmospheric processes in complex terrain impacting wind industry forecasts and incorporating the new understanding into the foundational weather forecasting models. The integrated WFIP 2 team will conduct a large scale field campaign to gather data from all four seasons in the Columbia River Basin of Washington and Oregon to assess how physical processes alter wind speeds at hub heights.

Following the field campaign, the team will work to develop physical modeling schemes or atmospheric theories that better represent physical processes and increase the accuracy of 0 to 15 hour wind energy forecasts with positive implications to the day ahead forecast while focusing on the wind plant inflow. NOAA's 13-km Rapid Refresh (RAP), 3-km High Resolution Rapid Refresh (HRRR), and 750-m HRRR nest use the open-source WRF model at the core and will be the focus of improvements to model physics at the mesoscale and smaller scales. Improved bridging of models across multiple scales is a focus of WFIP 2. Forecast uncertainties will be quantified using both data and ensemble techniques. Decision support tools will be developed that incorporate these uncertainties to better communicate forecast reliability to system operators and other users.

WFIP 2 follows the recently completed WFIP 1 as a second large-scale project in 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/National Weather Service/Environmental Modeling Center

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. As one of the nine NCEP Centers, EMC uses advanced modeling methods developed both internally and cooperatively with universities, the international scientific community, NESDIS, OAR, 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 conducts applied research and technology transfers and publishes 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 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/Hurricane Forecast Improvement Project (HFIP)

HFIP contributes significantly to NOAA's forecast services through improved hurricane forecast science and technology. HFIP provides the unifying organizational infrastructure and funding for NOAA and other agencies to coordinate the hurricane research needed to significantly improve guidance for hurricane track, intensity, and storm surge forecasts and accelerate the transition from research to operations. HFIP is in the fifth year of its mission to reduce track and intensity errors, increase the probability of detection and decrease the false alarm ratio for rapid intensification and extend the lead-time for hurricane forecasts out to seven days. HFIP approaches meeting those goals by improving existing numerical forecast systems through a regimen of revising, testing, refining and implementing promising technologies. HFIP developed a high-performance computing system housed at the NOAA Skaggs Building in Boulder, Colorado to support the significant computational demands of such an approach. With the computational infrastructure, HFIP focuses multi-organizational activities to research, develop, demonstrate and implement enhanced operational modeling capabilities, dramatically improving the numerical forecast guidance made available to National Hurricane Center (NHC). Participants include Federal laboratories and academic partners. Prior to each hurricane season, NHC reviews and selects a set of enhanced experimental guidance products they will evaluate operationally during the season. HFIP runs an experimental forecast exercise on the high-performance computing system in Boulder to provide the selected products to NHC forecasters.

HFIP's structured approach accelerates bringing promising technologies and techniques from the research community into operations. In particular, HFIP has successfully

- aligned focused research efforts within NOAA and with NOAA's interagency and academic partners;
- established a process to leverage outside research capabilities in support of project objectives (Federally funded grantees working within a community code repository);
- defined and implemented a solution (the seasonal, real-time experimental forecast system) to accelerate research into operational products; and
- established a high performance computing infrastructure and attendant protocols to support research-to-operations activities.

NOAA/National Environmental Satellite, Data, and Information Service

Center for Satellite Applications and Research (STAR)

As the primary science arm of NESDIS, STAR provides leadership for NESDIS research, development, validation, and maintenance of satellite-derived products and applications from NOAA's operational geostationary and polar-orbiting satellites and from many non-NOAA research and international satellites. STAR develops new environmental applications, techniques, and algorithms for transforming raw satellite observations into scientifically meaningful, quality–assured, and calibrated environmental measurements and products. STAR also develops the pre-operational computer codes to implement these products. STAR supports the calibration and validation of all satellite sensors used in NOAA's satellite operations and develops methods and maintains systems for inter-calibrating NOAA satellite data with other satellites in the international constellation of research and operational satellites. STAR collaborates with other

NESDIS and NOAA offices, universities, NASA and other U.S. agencies, and international organizations on exchange and evaluation of operational and research satellite data and products. The Joint Center for Satellite Data Assimilation (JCSDA)—collocated with STAR and the NWS Environmental Modeling Center (EMC) at the NOAA Center for Weather and Climate Prediction (NCWCP)—is a joint distributed center sponsored by NOAA, NASA, and Departments of the Navy and Air Force. In addition to STAR, the NOAA partners include the Office of Oceanic and Atmospheric Research (OAR) Atlantic Oceanographic and Meteorological Laboratory (AOML) and the National Weather Service's National Centers for Environmental Prediction (NCEP). The JCSDA was established in 2001 to accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate, and environmental analysis and prediction systems. JCSDA research and development directly supports NOAA and DoD in their operational environmental prediction responsibilities.

NOAA/Office of Oceanic and Atmospheric Research (OAR)

The OAR Research Laboratories and Programs conduct an integrated program of research, technology development, and services to improve the understanding of the Earth's atmosphere and to describe and predict changes occurring to it. OAR programs, laboratories and their field stations are located across the country. Scientists study, monitor and model atmospheric, oceanic and other processes that affect weather, air quality, water resources, and climate. By researching Earth's atmospheric system, OAR improves the understanding of weather and intense events such as hurricanes, tornadoes, winter storms, extreme precipitation, and severe thunderstorms in addition to seasonal droughts, and the effects of the changing climate on these events. OAR integrates these findings into environmental information products for weather support for forecast operations, disaster preparedness, emergency response and management, transportation safety and efficiency, renewable energy production, and other sectors of the economy affected by weather. These products improve critical weather and climate tools used by the private sector, government agencies, decision-makers, and the public.

OAR Laboratories and Programs

Air Resources Laboratory (ARL)

ARL supports basic meteorological products and services through research and development in atmospheric dispersion, air quality, and boundary layer science. Primary research activities and programs are 1) using the ARL-developed Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to track the transport, dispersion and fate of harmful chemicals and materials; 2) providing the Real-time Environmental Applications and Display sYstem (READY) that allows users to access and display meteorological data and run trajectory and dispersion model products on ARL's web server; 3) improving air quality forecasting models to address health issues associated with ground-level ozone (O3) and fine particulate matter (PM2.5) for NOAA and other researchers; and 4) designing, developing, and deploying meteorological and turbulence instrumentation for use on land and in the air.

In FY16, ARL will:

- Continue to apply the HYSPLIT model to track and forecast, as needed, the release of radioactive material, volcanic ash, dust, and wildfire smoke, and other hazardous materials. ARL will continue to provide HYSPLIT-Mercury assessments for the Great Lakes Restoration Initiative.
- Deliver to NWS a forecasting system tailored for global chemical transport model coupling capable of tracking smoke and dust plumes originating from outside the continental US.
- Explore the use of a small Unmanned Arial System as a contribution to the NOAA VORTEX-Southeast field campaign in Alabama to help understand the formation, intensity, structure and path characteristics of tornadoes.
- Continue work with NOAA's Office of Response and Restoration to make needed improvements to the integrated HYSPLIT-CAMEO/Aloha modeling system for short- and long-range atmospheric transport applications.
- Continue the development of a five- year re-analysis dataset, generated using the Community Multi-scale Air Quality model, to address O_3 and $PM_{2.5}$ for the benefit of the air quality and climate research communities. Generate a new forecast product using data from the Joint Polar Satellite System to link ocean isoprene emissions to changes in ozone and aerosols that affect air quality and climate.
- Prepare and deploy the Best Aircraft Turbulence probe as part of the Fluxes of Carbon from an Airborne Laboratory (FOCAL) system) for a study over the permafrost regions of Alaska.

Atlantic Oceanographic and Meteorological Laboratory (AOML)

AOML conducts mission oriented scientific research that seeks to understand the physical, chemical, and biological characteristics and processes of the ocean and atmosphere, both separately and as a coupled system. The Laboratory's research themes (oceans and climate, http://www.aoml.noaa.gov/research/ocean_climate.html; coastal ecosystems, http://www.aoml.noaa.gov/research/coastal_ecosystems.html; and hurricanes and tropical meteorology, http://www.aoml.noaa.gov/research/hurricanes.html) employ a cross-disciplinary approach, conducted through collaborative interactions with national and international research and environmental forecasting institutions. The work also provides reliable information based on oceanic and atmospheric measurements and analysis.

AOML scientists study atmospheric and oceanic processes that affect tropical cyclones, tornadoes, rainfall (drought), and climate impacts on weather. In addition to research, AOML serves as the operational data center for several programs that directly improve weather services through providing in situ observations from Argo profiling floats, surface drifters and the Pirata Northeast Extension. Research includes improved understanding and application development surrounding physical processes like the El Nino-Southern Oscillation (ENSO) phenomena, North Atlantic Oscillation (NAO), tropical Atlantic variability, the Meridional Overturning Cell, wind-driven gyres in the Atlantic, the global carbon cycle, and other climatically-relevant atmospheric compounds. Of particular note includes AOML research into tropical Cyclones and ocean observing technologies.

Ocean Observing Technologies

In addition to the many weather-related observing systems, AOML is dedicated to improving the development, deployment, and monitoring of oceanographic-related observing technologies and

related data in support of meteorology forecasts. As part of this effort, AOML collaborates with the National Weather Service to gather and transmit in real-time marine weather observations from ship-based observations. The AMVER SEAS 2K is a real-time ship and environmental data acquisition and transmission system (developed and support by AOML), reports atmospheric and oceanographic data from Ship of Opportunity Program. AOML also manages, in partnership with the Climate Program Office, the Global Drifter Program, the Argo profiling float data assembly center, and the XBT data assembly center that provide real-time oceanic observations to help improve weather 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 to advance the understanding and prediction of tropical cyclones. The observations are primarily collected during the hurricane season using two NOAA turboprop aircraft and a Gulfstream-IV jet operated by NOAA's AOC.

HRD's major objectives are the assimilation and evaluation of the new G-IV tail Doppler radar observations to improve forecast guidance, evaluation of the Global Hawk unmanned aircraft systems (UAS) observations to improve forecast guidance in collaboration with the NASA Hurricane Severe Storm Sentinel (HS3) program, and collecting observations specifically to evaluate the atmospheric and oceanic boundary layer physical parameterizations used in NOAA's operational Hurricane Weather Research and Forecasting (HWRF) model. As part of the OAR Sandy Supplemental supported research activities, HRD will evaluate and assess the benefits of using new and emerging observing technologies consisting of aircraft-deployed low altitude UAS and Doppler wind lidar (DWL) profiling systems to improve forecast guidance through evaluation of and improvements to the physical parameterization routines used in HWRF.

HRD is also the principal OAR component of NOAA's Hurricane Forecast Improvement Project (HFIP). Begun in 2009, 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 5-6 researchers at NCEP/EMC make up the NOAA core capability for hurricane R&D and play a major role in the HFIP. 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.

In support of OAR's Sandy Supplemental supported High Impact Weather Prediction Project (HIWPP), HRD is collaborating with NCEP/EMC to accelerate the development of a fully two-way interactive moving nested, multi scale, non-hydrostatic modeling system based on EMC-developed Nonhydrostatic Multiscale Model on B-grid (NMM-B) in the NOAA Environmental Modeling System (NEMS) framework. Multiple HWRF-like nests will be designed to operate at about 3 km resolution within a basin-scale and global version of NMM-B to capture tropical

cyclone inner core process and interactions with the large-scale environment, critical for improving track, intensity, rainfall and size predictions.

Earth System Research Laboratory (ESRL)

At NOAA's largest research facility, the Earth System Research Laboratory (ESRL), scientists (from four complementary divisions) study and monitor atmospheric and other processes that affect weather, air quality, water resources, and climate. By researching the dynamic Earth system, ESRL improves understanding of what causes today's weather, next month's hurricanes, next season's drought, and next century's climate. ESRL integrates these findings into environmental information products ranging from weather support for aviation and emergency management, to methods that improve critical weather and climate tools used by the private sector, government agencies, decision-makers, and the public. ESRL research is so comprehensive that it is impossible to give each program or project equal mention. The following description highlights a very small portion of products and services provided by ESRL.

ESRL provides long-term, high quality observations of atmospheric composition that are critical for understanding changes in the Earth system. These observations are used worldwide by scientists studying climate, air quality, and ozone-depletion. They form the core of international observing systems and are critical for delivering updates of key products such as CarbonTracker, the NOAA Annual Greenhouse Gas Index (a national climate indicator), methane climatologies, CO_2 trends (daily updates; a national climate indicator), the Ozone-Depleting Gas Index, GlobalView, and other long-term atmospheric composition data sets and products. They are used to set standards for GCOS, GEOSS, and WMO Global Atmosphere Watch. These observations stem from 6 global baseline observatories, ESRL-operated observing networks for stratospheric and tropospheric ozone, aerosols, surface radiation, ozone-depleting gases, and greenhouse gases, and a system of tall towers and aircraft observations across North America.

ESRL carries out process studies which improve understanding of the physics and dynamics associated with weather and other atmospheric phenomena. In FY16, ESRL will be a lead investigator on CalWater2, a broad interagency multi-year effort to better understand the formation, structure, and evolution of atmospheric rivers, as well as the impacts of aerosols on precipitation enhanced by orography. An extensive multi-platform field campaign was carried out in Jan.-Mar. 2015 in the eastern Pacific. In FY16, ESRL scientists will use the data collected during the NOAA-led CalWater and DEO-led ACAPEX 2015 field campaigns to learn more about atmospheric rivers and aerosol impacts. An evaluation of how well numerical models predict atmospheric rivers and their resulting precipitation will also occur. All of this research will result in presentations at international scientific meetings, such as those sponsored by AGU and AMS , and peer-reviewed publications. ESRL is active in Arctic research. This year ESRL will submit a report on the NOAA Science Challenge Workshop on the Arctic (held in Boulder in May 2014) that includes a summary of the workshop findings with recommendations for NOAA actions for the next 5-10 years.

The ESRL Global Systems Division (GSD) works with NOAA's National Weather Service, other federal agencies, and private companies to transition technologies into operations One of ESRL's most notable areas of achievement is development and R2O of numerical weather prediction products. Over the past several years, GSD has developed NWP models such as the

Rapid Update Cycle (RUC) and Rapid Refresh (RAP) and transitioned them to NWS operations. For over a decade, the RUC was NOAA's hourly-updated operational North American forecast model until it was replaced by the RAP model on May 1, 2012. The RAP increased coverage to all of North America, including Alaska. On September 30, 2014, the resolution became even finer at 3km when the High Resolution Rapid Refresh (HRRR) model became operational. The HRRR represents a significant new level of capability for NWS. The HRRR is a real-time 3-km resolution, hourly updated atmospheric model, initialized by the RAP model with 3-km radar data assimilation. The finer resolutions allow, for example, air traffic managers to find a safe path around thunderstorms to land planes, to identify potential severe weather for neighborhoods, to accurately forecast weather for wind turbine farms, and to provide more localized predictions for managing wildfires.

GSD is also developing higher-resolution regional ensemble guidance which provides more forecast uncertainty or probabilistic information, especially about severe weather. GSD is working with the NWS Environmental Modeling Center and the Developmental Testbed Center to develop the North American Rapid Refresh Ensemble (NARRE), providing hourly updates at a 12-km resolution. GSD continues to develop several global weather models, both hydrostatic and non-hydrostatic, based on the icosahedral grid to further accelerate improvements in the skill of US operational weather prediction systems and to be considered for the National Multi-Modal Ensemble (NMME).

Another successful transition involves the Meteorological Assimilation Data Ingest System (MADIS) which achieved Full Operational Capability at the National Weather Service in late January 2015. MADIS collects, integrates, quality controls, and distributes high-frequency observational weather data from both NOAA and non-NOAA sources. MADIS leverages partnerships with international agencies; federal, state and local agencies (e.g. states' Department of Transportation); universities; volunteer networks; and the private sector (e.g., airlines, railroads) to integrate and quality check observations from their stations. GSD continues to "grow" the MADIS database by adding the data and functionalities of other observing stations and networks.

ESRL/GSD builds technologies that educate current and future generations about our changing Earth. The Science On a Sphere® (SOS) global display system uses computers and video projectors to display animated earth science datasets on the outside of a six-foot diameter sphere. The SOS is an education tool which explains Earth system science in an intuitive and captivating way to people of all ages. In FY2015, the number of NOAA patented Science On a Sphere® installations in museums and other large venues world-wide increased to 120 and should expand to 128 in FY2016.

Over the next year, ESRL/GSD will be transitioning the following technologies to operations:

- New versions of the Rapid Refresh and High Resolution Rapid Refresh numerical weather models providing new capabilities will be implemented into operations in June 2015 and April 2016.
- MADIS will incorporate observation data from two significant networks: the Federal High Administration's *Clarus* (https://madis.noaa.gov/madis_comingsoon.shtml) and NWS' Hydrometeorological Automated Data System (HADS) and Automated Flood Warning Systems (AFWS).

- The first release of SOS Explorer™ will provide teachers and students access to visualizations of over 500 Science On a Sphere® datasets and movies for use in their own classrooms (http://www.sos.noaa.gov/SOS_Explorer/).
- ESRL signed a Cooperative Research and Development Agreement with the private sector to conduct collaborative research and development pertaining to deriving and improving Global Positioning System/Global Navigation Satellite System neutral atmospheric measurements known as GPSMet. ESRL/GSD intends to transfer the existing NOAA GPS-Met data acquisition and processing system technology to the private sector. Phase I has been completed and Phase II will be completed by the end of FY2015. Transfer of the GPS-Met capability is expected by the end of FY2016.

ESRL/GSD develops, operates and manages high-performance computer systems that enable running many of NOAA's experimental weather models. Enhanced technologies such as massively parallel fine grain computing allow massive amounts of data to run at higher spatial resolutions providing increased weather forecast accuracy. GSD develops techniques to prepare software to take advantage of these enhanced technologies from the private sector.

ESRL develops state-of-the-art forecast and decision-support systems to improve collaboration and decision-making between forecasters, emergency managers, and the public. These decision support systems provide decision-makers with additional tools to help them issue and communicate timely and accurate hazard information.

ESRL/Chemical Sciences Division research provides a scientific basis for efforts to improve air quality, and will continue to monitor long-lived gases in Earth's changing atmosphere to advance understanding of climate-related effects of short-lived pollutants, atmospheric particles, and their interactions with clouds. Additionally ESRL will continue collaboration with USDA/USFS to identify and quantify emissions of gases and aerosols from burning of different biomass materials for improvement of forecast models that provide air quality information to the public and to responders on-scene at wildland fires. They will continue participation in the Tropospheric Ozone Lidar Network (TOLNet) to further understanding of processes in the atmospheric boundary layer that affect ozone and aerosols.

Geophysical Fluid Dynamics Laboratory (GFDL)

The Geophysical Fluid Dynamics Laboratory (GFDL) mission is to advance scientific understanding of climate and its natural and anthropogenic variations and impacts, and improve NOAA's predictive capabilities, through the development and use of world-leading computer models of the Earth System. GFDL scientists focus on model-building relevant for society, such as hurricane research, prediction, and seasonal forecasting, and understanding global and regional climate change. GFDL research encompasses the predictability and sensitivity of global and regional climate; the structure, variability, dynamics and interaction of the atmosphere and the ocean; and the ways that the atmosphere and oceans influence, and are influenced by various trace constituents. The scientific work of the Laboratory incorporates a variety of disciplines including meteorology, oceanography, hydrology, classical physics, fluid dynamics, chemistry, applied mathematics, and numerical analysis.

Research 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 at regional scales. High-resolution atmospheric models with comprehensive treatment of physical processes are central tools in this work.

Ongoing research will continue to explore 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. Identifying the processes that are key to determining tropical cyclone frequency may allow us to extend dynamical forecast lead-time toward one year. GFDL will also continue to improve statistical methods for using coupled climate models to develop long-lead-time forecasts of seasonal hurricane activity, and experimental forecasts will continue to be updated on GFDL's website. Even longer lead-time predictions are targeted 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. Augmenting this research are decadal hindcast and prediction experiments yielding model-produced "predictions" for each year from 1961 to 2011. The ongoing analysis of these simulations seeks 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.

Complementing this effort is 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. Continued research in FY16 will focus on a better understanding of the response of global and regional climate to natural and anthropogenic aerosol emissions. GFDL's world-leading high-resolution models use the very latest numerical techniques to provide extremely energetic, realistic simulations of the climate system. Through their use in FY16, GFDL seeks to further scientific understanding of the role of the ocean and atmospheric constituents in climate variability and change, on regional to global scales. This research continues to exploit NOAA's 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 regional-scale 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)

The Great Lakes Environmental Research Laboratory (GLERL) develops and operates technology for scientific observations in the Great Lakes ecosystem. GLERL scientists acquire the data and develop information needed to improve our understanding of the Great Lakes ecosystem and support decision-making for improved resource management. Advancements in areas such as remote sensing, the miniaturization of sensors, and other data-gathering technologies have vastly increased the data gathering capacity of the scientific community.

Additionally, GLERL tests and applies models for predicting the effects of natural and human-generated changes on the Great Lakes environment. Modeling of the atmosphere, lakes, seasonal changes in ice cover, and the ecosystem dynamics of the lakes adds to our understanding of how the Great Lakes basin changes over the course of months and years. GLERL research on regional climate projections is based on atmospheric and coupled hydrodynamics-ice-ecosystem models. Research tools are designed to examine the effects of climate on regional air temperature, precipitation, water levels, lake temperature and thermal structure, ice cover, and ecological changes and trends.

In FY 16, priorities for the Great Lakes Environmental Research Laboratory (GLERL) include continuing research, development, and transfer of remote sensing products from the Great Lakes CoastWatch Node. GLERL will focus on satellite synthetic aperture radar (SAR) and moderate resolution imaging spectroradiometer (MODIS) ice classification and mapping. GLERL will also focus on continued data collection and analysis for the advancement of ice-ocean ecosystem modeling in the Artic. GLERL's hydrologic modeling program will advance the GLERL hydrometeorological database, improve Great Lakes basin runoff and evaporation estimates, and continue to enhance the Great Lakes hydroclimate dashboard. GLERL will continue efforts on regional climate projection impact assessment and historic trends analysis. GLERL will assess the similarity and differences between model runs from the Coupled Hydrosphere-Atmosphere Research Model (CHARM) with model runs from other GCMs. GLERL will continue to develop and validate modeling systems that contribute directly to projection of the overall water budget and levels of the Great Lakes, as well as enhances understanding of relevant climate change processes on a regional scale.

National Severe Storms Laboratory (NSSL)

The mission of the National Severe Storms Laboratory (NSSL) consists both of conducting *fundamental research* to advance our knowledge and understanding of meteorological processes associated with severe convective storms, as well as *applied research and development* leading to the transition of new and improved tools and techniques for observation, analysis, and prediction to the NWS and other stakeholders. These efforts are aimed at improving the accuracy and lead-time of severe weather forecasts and warnings, lending support to a Weather-Ready Nation that is resilient in the face of increasing vulnerability to severe and disruptive weather. In particular, NSSL seeks to improve the accuracy and timeliness of forecasts and warnings of severe thunderstorms, tornadoes, hail, flash floods, lightning, mixed precipitation in winter storms, and their societal impacts. Advancements in observing system capabilities and physical understanding of processes that produce hazardous convective weather are core to NSSL's fundamental research. Numerous gaps in our knowledge of these processes remain. NSSL provides leadership in the understanding of storm structure, processes, and evolution, and the use of polarimetric radar observations to understand the interrelationships among microphysics, dynamics, electrification, and lightning activity across a broad spectrum of convective storms.

Moving research to operations is a core part of NSSL's mission. More than two decades ago, NSSL pioneered development and use of Doppler radars to monitor convective storms and detect signatures of severe weather, which eventually led to the establishment of the national network of Doppler radars (WSR-88D). Our subsequent work demonstrated the ability of polarimetric radar to improve precipitation estimates and identify hydrometeor types, leading to a powerful

recent enhancement of the WSR-88D capabilities over the last couple of years. NSSL's basic research with lightning strike mapping systems contributed to incorporation of lightning strike data into NWS operations and provided a foundation for the development of applications for the future Geosynchronous Lightning Mapper (GLM). Experience with data integration systems led to the implementation of the Multi-Radar/Multi-Sensor System (MRMS) into NWS operations in October 2014, which has resulted in improvements to warnings for flash floods and other high impact weather. NSSL scientists have worked closely over the past two decades with the Storm Prediction Center (SPC) and NWS Forecast Offices at the Hazardous Weather Testbed (HWT) to demonstrate the value of cutting-edge ensemble weather prediction systems to determine the probability of a severe weather event.

NSSL's research for the next decade is focused around six "grand scientific challenges" representing challenging, yet achievable and societally important problems that. Specifically, NSSL scientists are seeking to attain the goal of the Warn-on-Forecast program in providing NWS forecasters with the probabilistic guidance needed to extend lead-times for severe thunderstorm and tornado warnings out to one hour with substantially reduced false alarms. Second, we consider it necessary to enhance WSR- 88D capabilities while addressing this aging operational radar technology, current gaps in radar coverage, and longstanding limits of tornado lead time with high false alarm rates by developing advanced radar concepts such as phased array radar. Third, NSSL is developing the capability to reliably predict flash flooding for both urban and complex landscapes several hours in advance, providing a probabilistic hydrologic prediction with much longer lead time and more accurate prediction than current systems. Fourth, our research seeks to demonstrate that useful warnings of lightning activity can be predicted one hour in advance from the very onset of convection to its demise, both in-cloud (as an indicator of storm intensity changes and short-term predictor of severe weather potential) and cloud-to-ground lightning (for public safety and aviation concerns). Fifth, our plans are to develop a reliable nowcasting system for convection initiation that goes well beyond the current reliance on surface, radar and satellite detection of low-level boundaries, so as to address fundamental gaps in our understanding of how the pre-convective environment is evolving in terms of available moisture, instability, wind shear, and storm generation mechanisms. Finally, NSSL will provide uncertainty information for high impact weather to reduce tornado and other severe weather warning false alarms significantly and provide the public with probabilistic, risk-based information to replace current "binary" yes/no warning areas. This is needed to greatly improve public decision-making to attain a better-informed Weather-Ready Nation that is resilient to dangerous, high-impact weather events.

Weather Radar Research. The NSSL continues to conduct basic and applied R&D aimed at exploring and advancing weather radar science and technology of existing and future weather radar systems. NSSL works closely with the NWS in R2O activities to evolve and improve the operational WSR-88D network (NEXRAD). These efforts are critical in maintaining the viability and operational relevance throughout the fleet's long projected life. Concurrently, NSSL is dedicated in exploring the next generation of weather radar and is partnering with the FAA to evaluate the feasibility of applying phased array radar technology to meet multi-agency requirements.

The operational deployment of dual polarization throughout the WRS-88D fleet has led to the discovery of unique polarimetric signatures that are proving to be useful in winter weather applications as well as showing promise in having prognostic and detection capabilities for

significant severe weather events. NSSL scientists are refining the Hydrometeor Classification Algorithm (HCA), in part, by combining polarimetric numerical model information to improve the HCA's classification capabilities near the Earth's surface, in particular for cases of winter weather. Operational algorithms are being developed that utilize polarimetric information. These algorithms will be useful in forecasting the potential for rapid convective development and transition of the storms into the dangerous supercell stage (Zdr columns and Zdr arcs) as well as the detection of tornadic debris that help to identify damaging tornadoes and pinpoint their locations.

NSSL continues to work to address data quality issues in the operational WSR-88D network. Techniques have been developed to improve ground clutter mitigation performance. Clutter contaminants artificially inflate/deflate quantitative precipitation estimates (QPE) and can obscure weather estimates. Other techniques to address range-and-velocity ambiguity mitigation have been developed and have been transitioned to the WSR-88D and will improve the ability to detect severe weather, flash floods, winter storms, and provide aviation forecasts.

NSSL is also actively engaged in a risk reduction activity for the Multifunction Phased Array Radar (MPAR) technology with the Federal Aviation Administration (FAA) and industry in designing and testing dual-polarized phased array radar panels (see Section 3, Aviation Services). These activities are an effort to determine the feasibility of using MPAR as the replacement technology for weather and aircraft surveillance radars (i.e. multi-function). A recent accomplishment this year was the successful development of a small-scale (consisting of 640 transmit/receive elements) dual-polarization phased array radar in collaboration with the Massachusetts Institute of Technology Lincoln Laboratory. The major MPAR risk reduction activities for FY16 are to test and evaluate the small-scale dual-polarized phased array radar demonstrator.

Since 2003, NSSL has improved the capabilities of the National Weather Radar Testbed (NWRT) Phased Array Radar (PAR) to demonstrate the potential of PAR technology to simultaneously perform aircraft tracking and weather surveillance. Emphasis has been placed in developing proof-of-concept strategies for focused and tailored observations of weather. Case studies and Phased Array Radar Innovative Sensing Experiments held in the HWT are examining the importance of these rapid-scan radar data to understanding severe storm processes and improving the accuracy of severe thunderstorm and tornado warnings.

High Impact Hazardous Weather Research. NSSL is taking the lead on a groundbreaking project called Warn-on-Forecast (WoF). This research project aims to create computer-model projections that accurately predict storm-scale phenomena such as tornadoes, large hail, and extreme localized rainfall. The goal of WoF is to provide NWS forecasters with reliable guidance for the likelihood of each of these phenomena at any location up to an hour before they strike, enabling a new early-warning paradigm for extreme localized weather events.

NSSL is actively engaged in several lightning research projects, including three different approaches to the assimilation of lightning data into forecast models (e.g., nudging water vapor mixing ratio to force convection in the WRF-ARW, employing an operator to assimilate lightning data into an EnKF model, and investigating relationships between lightning bursts and changes in the intensity of inner-wall convection of hurricanes).

NSSL is also testing and refining new ground-based remote sensing instruments that can provide frequently updated observations of the temperature, moisture, and wind fields in the lower atmosphere. Knowledge about rapid changes in these fields is a key piece of information that has the potential to significantly enhance prediction and warning of rapidly developing weather hazards, particularly severe thunderstorms. NSSL is developing and testing trailer-based mobile observation platforms containing these instruments. These platforms can be strategically placed "on-demand" to provide these key observations and advance forecasting and warning capabilities.

Revitalizig the Warning Decision Process. NSSL is working with the NWS to develop a new 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. Within the next decade, NSSL envisions operational units using 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. To make the best use of these technological advances, NSSL is collaborating with the NWS in the exploration and development of a new paradigm for hazardous weather forecasting known as Forecasting a Continuum of Environmental Threats (FACETs). FACETs is intended to move the NWS from a deterministic, binary, product-centric system to one in which a rapidly-updated, high-resolution stream of (probabilistic) hazardous weather information, fed by current and future scientific tools (e.g., WoF, PAR) can be optimized for user-specific decision making. As such, FACETs represents a fundamental change in the nation's hazardous weather forecasting system.

Office of Weather and Air Quality (OWAQ)

NOAA's Office of Weather and Air Quality (OWAQ) improves weather and air chemistry forecast information and products by funding, facilitating, and coordinating research, as well as supports the transition of research results into operations. By working with scientists and academic partners, this research is transitioned into useful weather applications, watches and warnings to protect the lives and property of the American public and inform weather-sensitive U.S. industry. OWAQ provides outreach, linkages, and coordination between NOAA, other Government agencies, academia, the private sector, and non-profit research partnerships, particularly NOAA's Cooperative Institutes and Cooperative Science Centers. OWAQ additionally supports social science studies to test research results that improve communication during dangerous weather situations.

In FY16, OWAQ will continue supporting projects through the U.S. Weather Research Program (USWRP) to improve high-impact weather and air quality forecasting and also improve NOAA's global modeling system from days to months through the National ESPC project. National, as well as supporting the transition of weather research results toward National Weather Service operations. and decadal OWAQ will also support testbeds and high-resolution numerical model improvements to enable better high-impact weather forecasts, including tropical cyclones, extreme precipitation, and severe thunderstorms. In addition, air quality modeling research will contribute to improving National Weather Service smoke, dust, and volcanic ash predictions. OWAQ will also fund social science research that helps to understand how society uses and

interprets weather information and how to improve the communication of weather information to the public.

Pacific Marine Environmental Laboratory (PMEL)

Meteorological research at PMEL focuses on air-sea interaction research in the Gulf of Alaska Bering Sea, and Chukchi 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, the North Pacific Research Board (NPRB), and the DOI/Bureau of Ocean Energy Management (BOEM).

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.

PMEL conducts research on atmospheric aerosols and their impact on air quality and climate. In 2016 (November) and 2017 (May), PMEL is participating in NAAMES (North Atlantic Aerosols and Marine Ecosystems) research cruises. NAAMES is a multi-platform, interdisciplinary investigation focused on marine ecosystems and aerosol properties in the climate sensitive North Atlantic. NAAMES will study the annual life cycle of phytoplankton and the impact small airborne particles derived from marine organisms have on climate in the North Atlantic. PMEL will make shipboard measurements to characterize the emission, properties, and cloud nucleating ability of sea spray aerosol over a range of ocean conditions and seasons.

NASA Supporting Research for Basic Meteorological Services

Research in Basic Meteorology and Atmospheric Science

The FY 2016 budget will fund research competitively selected in FY 2015 through NASA's Research Opportunities in Space and Earth Sciences 2014 (ROSES-14) grant application solicitation. This ROSES opportunity addresses Severe Storm Research and will fund investigations that use measurements acquired from the vantage point of space to:

- Conduct basic research on the formation and intensification of severe storms that lead to the formation of tornados; and
- Assess if satellite-based products, coupled with advanced algorithms and models, can result in more accurate forecasts and warnings.

Many of the research activities carried out in FY 2016 will be tasks initiated in FY 2014 based on the earlier ROSES-13 solicitations. Selections based on ROSES-13 are ongoing and are addressing diverse Earth Science research areas. NASA sponsored research continues to gain new insight into weather and extreme-weather events by the utilization of data obtained from a variety of NASA- and partner satellite platforms and hurricane field experiments.

In addition, NASA has a long history of conducting airborne field campaigns in support of hurricane research (http://airbornescience.nsstc.nasa.gov/field/). During June and July 2015, NASA's instrumented DC-8 research aircraft will participate in the Plains Elevated Convection at Night (PECAN) experiment. PECAN is a large meteorology experiment sponsored by NSF, NOAA, NASA, and DOE. The scientific goal of the project is to collect data before and during nighttime severe storms in order to learn how they form, why some become severe, and how to predict them better. Most recently, NASA's ER-2 instrumented research aircraft participated in CalWater 2015, a multiagency, interdisciplinary field campaign to study atmospheric rivers, short-lived weather events that carry a flood of moisture from the tropics to the U.S. West Coast. Further, the Hurricane and Severe Storm Sentinel (HS3) Mission, a five-year Earth Venture Class Suborbital mission that was awarded in 2010, has obtained data from its base at the Wallops Flight Facility (WFF) on the coastline of Virginia during the hurricane seasons of 2012-2014 (https://espo.nasa.gov/missions/hs3/). This campaign used Global Hawk (GH) unmanned aircraft systems (UAS) and the NASA WB-57 manned aircraft with distinct payloads to address both inner-core and near-storm environmental science objectives. The HS3 Mission was designed to investigate some basic questions regarding changes in hurricane intensity:

1. What impact does the large-scale environment, particularly the Saharan Air Layer (SAL), have on intensity change?
2. What is the role of storm internal processes such as deep convective towers?
3. To what extent are these intensification processes predictable?

Over three years of measurements, HS3 performed 19 overflights of 9 named Atlantic tropical cyclones and also sampled several non-developing tropical waves and the Saharan Air Layer. Analysis of the data is ongoing in FY15 and will be completed in FY16.

To aid in its advanced planning process, NASA held the *Workshop on Scientific Challenges and Opportunities in NASA Weather Focus Area* in April 2015, gathering community leaders from NASA, NOAA, DoD, FAA, OFCM, NGOs, academia, industry, and international organizations. Participants identified some of the most challenging scientific research and development topics, which will be used to inform future program planning for the NASA Weather Focus Area, as well as provide inputs to the Earth Science Decadal Survey and NASA's Earth Science Technology Office.

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 (0 to 48 hours) 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 FY2015, NASA continued the investment in SPoRT and the external research projects to accelerate the transition of research data to operational environments. Several proposals funded by ROSES-13 program element "NASA Data for Operation and Assessment" will continue and

finish efforts in FY15. In FY2016, NASA plans to announce another run of NASA Data for Operation and Assessment ROSES element.

Technology Development

Technology investments are aligned with NASA's *Climate Centric Architecture* strategic document. A majority of the investments are centered on 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. The Earth Science Technology Office (ESTO) 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 regularly through the ROSES solicitation, and the duration of each project is typically three years. For FY 2015, ongoing investigations will be managed in the Instrument Incubator, Advanced Information Systems Technology, Advanced Component Technology, and In-space Validation of Earth Science Technology areas. New investments will be awarded in FY 2015 under the In-space Validation of Earth Science Technology area through a 2015 ROSES solicitation. Of note, in early FY 2015 a new radiance instrument, the HyperSpectral Imager for Climate Science (HySICS), made a successful balloon flight, collecting the most accurate solar radiance measurements (calibrated to the Sun to better than 0.2 percent radiometric accuracy) that have ever been made of the Earth. FY 2016 will see the release of the AIST-16 ROSES solicitation, and the launch of IceCube, a three unit CubeSat under development to validate a new 874-GHz radiometer for use in future ice cloud measurement missions.

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 2016 the Applied Sciences Program will continue to initiate projects across a range of application areas, including health and air quality, water resources, disasters, and ecological forecasting. The Program's Capacity Building element sponsors programs and projects that improve the skills and capabilities of decision makers, community leaders, and resource managers in the United States and abroad related to accessing and applying Earth observations. NASA will continue to build such capacity through the SERVIR, DEVELOP, and Applied Remote SEnsing Training (ARSET) program elements. The SERVIR program is a joint venture between NASA and the U.S. Agency for International Development (USAID), which provides satellite-based Earth observation data and science applications to help developing nations in Eastern and Southern

[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*.

Africa, the Hindu Kush-Himalaya, the Mekong, and Mesoamerica to improve their environmental decision-making. In FY2016, SERVIR plans to extend work into West Africa. The NASA DEVELOP program fosters an interdisciplinary research environment for interns to work on applied science research projects with a local government partner under the guidance of NASA and partner science advisors. The ARSET project trains decision-makers and applied science professionals in the areas of water resources, disasters, health/air quality, land, and wildfire management to use NASA's Earth Science observations, tools, and models to support their 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. NSF awards grants to single investigators or small collaborative groups working on specific topics, as well as larger interdisciplinary groups and the National Center for Atmospheric Research. NSF also supports the operation of a number of systems intended for community use, such as the NSF/NCAR GV research aircraft and the Center for Severe Weather Research Doppler on Wheels.

Examples of recent award topics related to meteorological services include mesoscale predictability, boundary layer processes, and numerical modeling techniques. NSF also continues to support the analysis of data collected during recent major field campaigns dealing with tornadoes, hurricanes, winter storms, and the Madden Julian Oscillation. NSF is funding a large field experiment that will explore nocturnal organized convection in the US Plains states during the Summer of 2015, called the Plains Elevated Convection at Night (PECAN) campaign. NOAA will be an interagency partner in this effort. In FY15, NSF is running a second competition for the Interdisciplinary Research in Hazards and Disasters program, which falls under the Science, Engineering and Education for Sustainability (SEES) portfolio in NSF. The first competition funded awards relevant to basic meteorological services, including the mitigation and response to hurricanes, tornadoes and flash flooding. The FY16 budget request also introduces a new activity called PREEVENTS (Prediction of and Resilience against Extreme Events) which falls under the NSF Risk and Resilience umbrella.

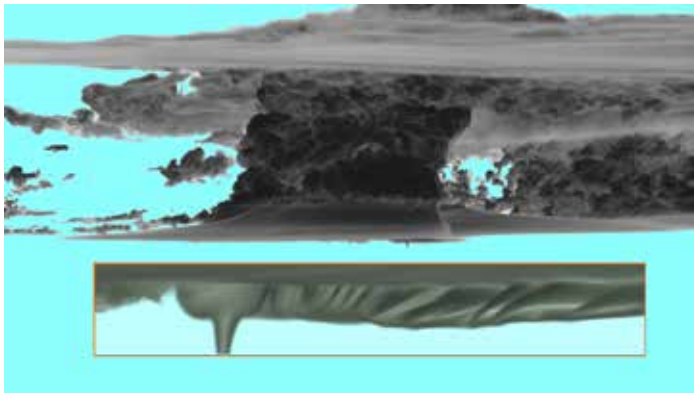


Figure 4: The figure above is a visualization of the cloud field of a tornadic supercell thunderstorm. Main image: The view of the supercell thunderstorm from a distance of about 50 km. Visible features include a rotating updraft (mesocyclone), overshooting thunderstorm top, anvil, and tornado. Inset: A close-up view of the tornado, wall cloud, and tail cloud. The simulated tornado is on the ground for an hour and a half and produces winds in excess of 300 miles per hour near the ground. Credit: Leigh Orf, Central Michigan University Robert Wilhelmson, University of Illinois

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

Interagency Programs

Joint Agricultural Weather Facility (JAWF)

In 1978, the World Agricultural Outlook Board (WAOB) and the National Oceanic and Atmospheric Administration (NOAA) formed the Joint Agricultural Weather Facility (JAWF). JAWF is as an operational unit, serving as an important link between the respective meteorological components of the Departments of Agriculture and Commerce. Additional information on the JAWF is included in the U.S. Department of Agriculture narrative below and at http://www.usda.gov/oce/weather/.

U.S. Department of Agriculture

Office of the Chief Economist

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. Because weather and climate have a significant impact on agricultural production, the WAOB employs meteorologists who specialize in preparing agricultural weather assessments, the group being collectively referred to as OCE/WAOB's Office of the Chief Meteorologist (OCM).

The primary mission of OCM staff 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, keeping USDA commodity analysts, the OCE, and the Secretary of Agriculture and top staff well informed of weather impacts on crops and livestock worldwide. These assessments are integrated into USDA's monthly analytical process to develop monthly foreign crop estimates of area, yield, and production published in the monthly WASDE reports.

In addition to providing routine agricultural weather assessments, OCM meteorologists prepare special assessments when extreme weather (e.g., droughts, heat waves, freezes, floods, and hurricanes) has been observed or is imminent. Alerts of anomalous weather conditions impacting agriculture around the globe are also routinely included in a daily report of agricultural developments that is sent to USDA policy makers each afternoon. 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.

While many of the group's core functions are internal, OCM staff routinely disseminates information to the public. 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 OCE website: http://www.usda.gov/oce/weather/pubs/Daily/TODAYSWX.pdf. The meteorologists also routinely give public interviews, available not only through USDA's Information Office but also private sector media outlets. In 2012 and 2013, for example, OCM staff played a key role in providing assessments of the historic drought that impacted much of the Nation's agriculture by conducting interviews with national and international news outlets and disseminating unique products and assessments via the USDA homepage and blog.

In support of its mission, the OCM receives a full suite of meteorological data and products from the NWS for use in their assessments, including surface weather observations, radar data, satellite imagery, and model output. As part of the aforementioned JAWF agreement, the OCM serves as the focal point for dissemination of meteorological data and products to other USDA agencies, including weather data received from the Global Observing System, a worldwide network of nearly 8,000 meteorological reporting stations managed by the World Meteorological Organization (WMO). Additionally, the OCM obtains data from the NWS Cooperative Observer Program (COOP) to support domestic agricultural weather applications. In recent years, the NWS, National Hurricane Center (NHC), CPC, and the Hydrometeorological Prediction Center have supported USDA by providing an increasing number of their operational products in GIS-compatible formats. These NOAA GIS efforts have benefited the OCM significantly by increasing the speed and efficiency with which agricultural weather assessments can be prepared and enabling analysts to more accurately assess weather impacts on agriculture.

JAWF's flagship publication, the *Weekly Weather and Crop Bulletin (WWCB)*, is jointly produced by the OCM, 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 *WWCB* highlights weekly meteorological and agricultural developments on national and international scales, via numerous maps, charts, tables, and text products. In total, these products provide a comprehensive illustration of the weather and climate conditions affecting agriculture, benefiting USDA decision makers and the agricultural community. Crop and weather information provided in the *WWCB* keeps crop and livestock producers, farm organizations, agribusinesses, state and national farm policy-makers, government agencies, and foreign buyers of agricultural products apprised of worldwide weather-related developments and their effects on crops and livestock. The 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.

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. While providing timely weather and crop information relevant to the monthly *Crop Production* and *WASDE* reports (issued by USDA/NASS and USDA/OCE/WAOB, respectively), the *WWCB* keeps the U.S. agricultural sector apprised of weather conditions impacting agriculture in foreign markets, which could possibly influence production decisions at the farm level.

In September 1994, the OCM published *Major World Crop Areas and Climatic Profiles* (Agricultural Handbook No. 664). 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, and 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. 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. No longer issued in a paper format, an electronic version of the handbook was developed to provide periodic updates to the printed version as additional data become available. The *Major World Crop Areas and Climatic Profiles* book and other publications are available online at http://www.usda.gov/oce/weather/pubs/index.htm.

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), USDA, CPC, the NOAA/NESDIS/National Climatic Data Center, and the Desert Research Institute. Approximately 11 lead authors, two of whom work for the OCM, 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 Website at http://droughtmonitor.unl.edu. The USDM, released each Thursday at 8:30 a.m. Eastern time, is a key source of information for briefing USDA top staff on U.S. drought developments. In recent years, the USDM has served as a trigger mechanism for several USDA programs and, 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 (**Figure 1**). In 2013, OCE entered into a cooperative agreement with the NDMC to improve U.S. agricultural drought monitoring capabilities and assessments by integrating USDA agricultural statistics and other relevant data sets into a GIS format to improve author's ability to incorporate various information types into their analytical process.

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 – two of whom are OCM staff – as well as Agriculture and Agrifood Canada and the National Meteorological Service of Mexico. The NADM Website 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 13-17, 2015, in Reno, Nevada, while a North American Drought Monitor Forum was recently held on June 17-19, 2014, in Toronto, Canada.

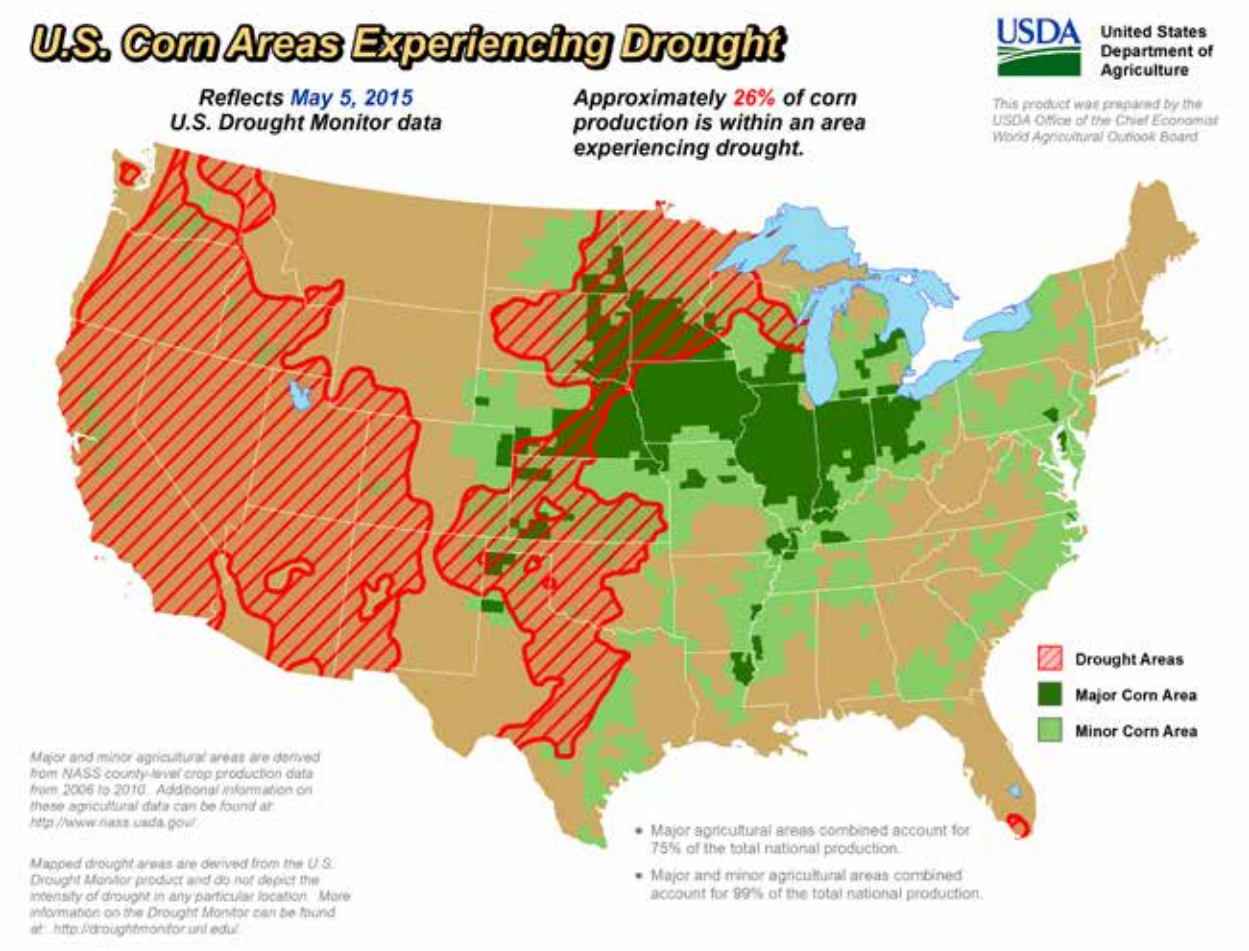


Figure 1. Percent of U.S. corn area in drought, according to the May 5, 2015, *U.S. Drought Monitor*.

OCE is one of several USDA agencies that have taken a lead role in the development of National Integrated Drought Information System (NIDIS), working closely with lead Federal agency NOAA and the Western Governors Association (WGA) over the years to address the specific needs of the agricultural community. The 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. Recommendations for such an early warning system were outlined in a 2004 report from the WGA entitled *"Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System."* One of the early deliverables of NIDIS was the Drought Portal (http://www.drought.gov), which serves as the Government's

multi-agency drought interface. The OCM is working with other USDA agencies to provide relevant drought information to the public via the Drought Portal.

As a result of the aforementioned activities with the NDMC, NOAA, and other agencies and organizations, OCE is a recognized leader within the USDA in the area of drought. In December, 2012, a Memorandum of Understanding was signed between USDA and NOAA to collaborate on projects of mutual interest, with particular emphasis on establishing new partnerships in the area of drought monitoring and mitigation. OCE enjoyed a lead role in developing the agreement and is currently working with NOAA to develop a work plan to identify near- and long-term deliverables and opportunities for collaboration. In 2014, USDA announced the creation of seven Climate Hub and three Sub-Hub locations. Under the direction of OCE's Climate Change Program Office, the Climate Hubs will deliver science-based knowledge, practical information and program support to farmers, ranchers, forest landowners, and resource managers to support decision-making related to climate change. Key partners in the networks include the public and land grant universities, Cooperative Extension, USDA researchers, the private sector, state, local and regional governments, the National Oceanic and Atmospheric Administration (NOAA), Department of Interior (DOI) regional climate change experts, and non-profits engaged in providing assistance to landowners.

Throughout its history, WAOB has successfully worked with international groups, including representatives of foreign governments and of multinational organizations. WAOB remains active in the World Meteorological Organization (WMO) Commission for Agricultural Meteorology (CAgM), and 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.

Risk Management Agency

The Risk Management Agency (RMA), Strategic Data Acquisition and Analyses (SDAA) unit works with Oregon State University's Parameter-Elevation Regressions on Independent Slopes Model (PRISM) Climate Group through the Center for Agribusiness Excellence (CAE), Tarleton State University, to produce and utilize innovative spatial climate data sets to identify and investigate potentially fraudulent crop loss claims. CAE manages RMA's day to day operations of the Agency's data mining and data warehouse operations and Oregon State University's PRISM Climate Group is a leader for spatial climate analysis. It produces the USDA's official normal (30-year average) data sets of temperature and precipitation for the United States, as well as time series of climatological variables spanning 1895-present.

High-quality weather and climate data is a key factor in improving the integrity and efficiency of the Federal crop insurance program. Precipitation, with its high spatial variability and importance in crop production, stands out as a climate variable that, on the one hand is essential to estimate accurately, but on the other suffers from insufficient observations. Existing precipitation networks are not sufficiently dense to capture the spatial variability of precipitation, especially during the growing season, when convective systems with spotty precipitation patterns are the rule. Snowfall is not measured accurately by most automated systems, resulting in poor wintertime observations over much of the US.

The program weakness addressed by PRISM is that many crop loss claims involve parcels that are distant from the nearest climate station, requiring that climatic conditions for those parcels be estimated. PRISM data sets are interpolated to a regular grid, and can be queried to provide estimates at any location across the United States. In addition, the PRISM data sets are recognized as the most accurate source of spatial climate data available. As such, they are a principal data source in an overall model for synergistically using climate information and local-to regional-scale ground-truthing to characterize the validity of crop insurance claims. Based on their long history of developing observation-based climate products, PRISM also has a unique capability to provide expert interpretation of the data sets and their quality. This project is designed to utilize and improve the accuracy of PRISM spatial climate data sets, and provide for expert interpretation of these data sets for crop loss insurance claims.

PRISM also provides RMA and the Approved Insurance Provider's (AIP's) operational support through a web based program that allows the AIP's to substantiate weather events and producers claims much faster which can expedite the claims process. The precision offered through the web based system offers major improvement over other data the agency has used in the past, because some events can be extremely local.

Department of Interior

Bureau of Land Management, Land Management Services

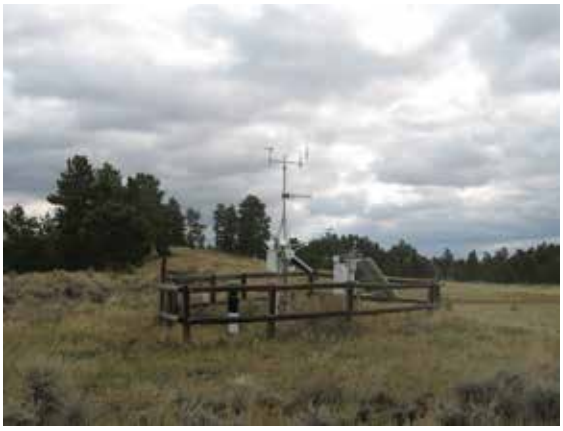


Figure 2: Meteorological Station at South Coal, WY

The Department of Interior's (DOI) Bureau of Land Management (BLM) utilizes air-resource-related (air quality, weather, and climate) information in order to manage public lands in a manner consistent with Congressional direction as expressed in the Federal Land Policy Management Act (FLPMA). FLPMA directs the BLM to periodically and systematically inventory resources through a land-use planning process and to manage public lands in a manner that protects the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, as well as other natural resources. 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 to 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.

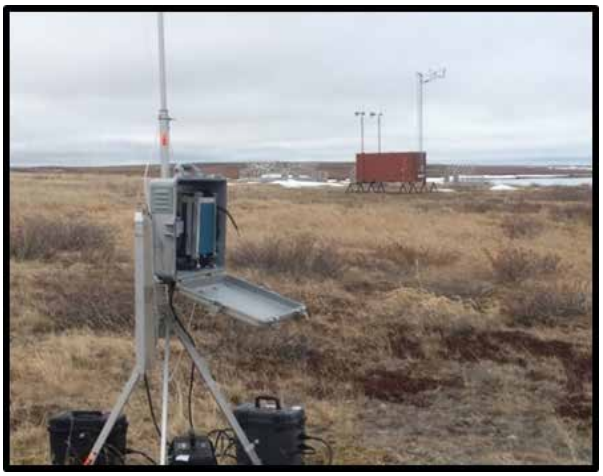


Figure 3: Portable ozone monitor with high quality PSD level meteorological station in background (Inigok, Alaska).

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

U.S. Department of Agriculture

Agricultural Research Service

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.

Weather-related research by ARS develops technologies to enable agriculture to cope with, and when possible benefit from, the effects of weather on crop and livestock production and natural resources and ecosystem services. Weather and climate data inputs and an understanding of weather-driven processes are critical to the development of crop growth and yield models, erosion models, nutrient cycling models, soil-plant-atmosphere process models, and many other simulation tools needed to provide continual advancements for agriculture. Such simulation tools are the foundations for the development of decision-support systems used for day-to-day decision making by producers and land managers, and policy-related decisions by strategic decision-makers. The Agricultural Model Intercomparison and Improvement Project (AgMIP) is a collaborative global effort to develop an ensemble crop yield estimation effort driven by the availability and use of weather data.

The interactions between genetics, environment (heavily focused on weather) and management practices (G x E x M) are under investigation as an approach to meeting the goals of sustainable agriculture as weather affects 1) the quantity and quality of desired yields, 2) the environment needed for agriculture and ecosystem services, 3) the economic viability of agriculture, and 4) the quality of life for rural populations and society as a whole. These goals are approached through a research strategy of: measure and understand, develop process-model prediction capacity, and then develop management technologies. Weather data and forecasting are integral to the research and applications of the research.

It is essential that crops and livestock be able to withstand weather stresses and losses from insect and disease exacerbated by the impacts of weather variations. Thus, the development of new crop and livestock varieties is a foundation of ARS weather and climate research. The interaction of water and high temperatures are of special interest.

The interactions of management systems and genetics are tempered by weather. ARS weather research is pursuing the hypothesis that the development of basic understandings and process models of the interacting effects of crop varieties with specific management practices adapted to weather means and extremes offers promise towards meeting the challenges of expanded food production for a growing world population.

The ARS Long Term Agro-ecosystem Research (LTAR) network is distributed geographically to provide a coordinated outdoor laboratory environment encompassing regional and local weather differences. The geographic diversity and the ability to obtain weather data and data on weather-driven processes that can be compared over time and space are critically important strengths of the LTAR. Weather data are a foundation of LTAR measurements. ARS collaborates with domestic and international colleagues, including universities, NASA, NOAA, USGS, state and tribal organizations, and industry.

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) provides the basis for the Department of Commerce, through National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS), to provide "meteorological services necessary for the safe and efficient movement of aircraft in air commerce" based on recommendations from Federal Aviation Administration (FAA). Domestically, NWS is designated as the National Meteorological and Hydrological Service Provider and FAA is the United States designated Meteorological Authority for aviation weather services for the United States mission to the International Civil Aviation Organization (ICAO). The FAA is implicitly responsible for ensuring compliance with the services as defined and with maintaining ICAO Standards and Recommended Practices as specified in Annex 3, Meteorological Service for International Air Navigation.

The Department of Defense (DOD) service branches (U.S. Army, Navy, Air Force, and Marine Corps), and the Department of Homeland Security service branch (Coast Guard) provide their own aviation weather support. 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.

Interagency Collaborative Operational Products and Services

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 maintains the National Volcanic Ash Operations Plan for Aviation. The purpose of the plan is to provide operational guidance by documenting the required procedures and information products of the government agencies responsible for ensuring safety of flight operations when volcanic ash has erupted into the atmosphere. This document also provides information on how the FAA, as the U.S. 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 website at http://www.ofcm.gov. Regional plans typically also involve State and local agencies.

Figure 1: Volcanic ash hazards can be catastrophic to aviation operations.

USGS. Through its five Volcano Observatories (Alaska, California, Cascades, Hawaiian, Yellowstone), the USGS is responsible for monitoring volcanoes in the United States and issuing notifications about volcanic activity 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). 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 to aid in its forecasting and tracking of ash clouds. Because of the proximity of Alaskan 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 by other agencies to mitigate the risk from airborne volcanic ash. USGS notifications and warnings about current volcanic activity throughout the United States are available to the public online at http://volcanoes.usgs.gov/ and through a free email subscription service at http://volcanoes.usgs.gov/vns/.

USGS works on a number of fronts with FAA, NOAA, and DOD, as well as with ICAO, to improve capabilities detect and warn of the presence of volcanic ash in flight routes, both domestic and international. USGS Volcano Observatory scientists participate in ICAO-led international exercises to practice coordinated response to an ash-producing eruption USGS has developed a display and analysis tool for accessing satellite data from a variety of sensors, which is being used collaboratively with NOAA's Anchorage and Washington Volcanic Ash Advisory Centers to improve ash-cloud detection capabilities. USGS also has developed an ash dispersion and deposition model (called Ash3D) that provides ash fall forecasts to support the NWS in Alaska in its issuance of ash fall warnings for the public.

Recognizing that many potentially dangerous volcanoes have inadequate or no ground-based monitoring, the USGS 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)" (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. 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 reliably 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 characteristics 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

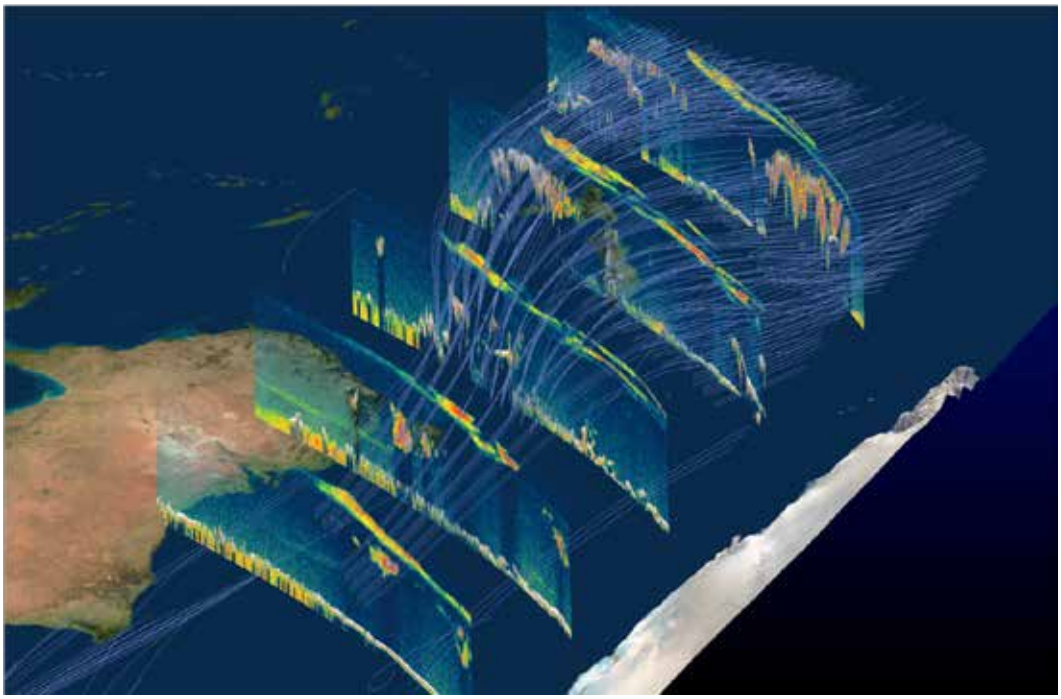


Figure 2: Sequence of CALIPSO 532 nm total attenuated backscatter curtains for 20 - 24 June 2011, depicting the passage of the Puyehue-Cordón Caulle volcanic ash cloud (yellow) near 8-12 km (20,000-40,000ft) across a large area from north Antarctica to Southeast Australia, Tasmania, and New-Zealand. The blue lines between the curtains illustrate forward model trajectories produced from the CALIPSO observations of the volcanic ash cloud. (Kurt Severance, NASA Langley Research Center)

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 primarily 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), Cross-track Infrared Sounder (CrIS) and the Ozone Mapping and Profiler Suite (OMPS) onboard. Suomi NPP is in partnership with NOAA. OMI and OMPS data, in which sulfate aerosol is used as a proxy for detecting volcanic ash, provide very accurate maps of the horizontal distribution of volcanic ash clouds, especially during the first several days following an eruption. Future NOAA Polar Operational Environmental Satellites (POES), will also deploy OMPS. In FY 2013, NASA began making CALIPSO Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) data and products available in near-real time for operational use. These data have been demonstrated to be of particular utility for improving trajectory model forecasts of volcanic ash, validating the location of volcanic ash determined by forecast models, and resolving the vertical structure and layering of ash clouds. The 30-meter High-resolution imagers on the Advanced Spaceborne Thermal Emission and Reflection (ASTER) instrument from the NASA Terra spacecraft can also be scheduled on a limited basis, and NASA-built sensors on NOAA Geostationary Operational Environmental Satellites (GOES) and POES also support volcanic ash monitoring. The NASA Science Mission Directorate, Earth Science Division, Applied Sciences Program, Disaster Area is currently responsible for developing satellite data applications for volcanic ash and is focused on extending research in which the Agency has employed these satellite measurements to improve the accuracy of trajectory model forecasts to improve aerosol dispersion (ash concentration) model forecasts for the Volcanic Ash Advisory Centers (VAACS). In addition, the NASA Jet Propulsion Lab (JPL) developed and began testing small, dedicated Dragon Eye Unmanned Aerial Systems (UAS) in 2013 which penetrate volcanic plumes and coordinated these measurements with ASTER observations allowing scientists to compare sulfur dioxide concentration derived from the satellite with UAS measurements taken from within the plume. In 2014, scientists also began to deploy rapid response balloon teams to measure volcanic aerosol plume characteristics needed to calibrate satellite retrievals such as those taken by CALIPSO to extend forecast capabilities beyond trajectory mapping to be able to begin to accurately estimate the mass loading of volcanic plumes. The NASA Aeronautics Research Mission Directorate (ARMD) also conducts volcanic ash research. Its efforts primarily concern the NASA ARMD Fundamental Aeronautics Program's Vehicle-Integrated Propulsion Research (VIPR) Project, which is a joint research project between NASA, USAF, USGS, FAA and the three largest engine manufacturers to determine propulsion system tolerances and thresholds for ingesting various concentrations of diffuse, persistent volcanic ash for increasing exposure periods. This purpose of this research is to improve the understanding of volcanic ash behavior and impacts in modern aircraft propulsion systems, to inform the development of operating procedures for operating in or near volcanic ash environments, and to develop improved aircraft engines and systems.

NOAA. NOAA/NWS is responsible for aviation-related volcanic ash forecasting services in the United States. The program is currently managed under the Aviation and Space Weather 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 website at http:/www.ofcm.gov. As noted earlier, NOAA/NWS also operates the Anchorage VAAC and partners with NESDIS, which operates 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.

NOAA/OAR (Office of Oceanic and Atmospheric Research) Air Resources Laboratory (ARL) also participates to support NOAA's volcanic ash services. ARL will be conducting research and development to improve the volcanic ash application of the ARL-developed HYSPLIT transport and dispersion model that is used by the NWS/NCEP to support the U.S. VAACs. In particular, ARL will work to (1) improve the quantification of the initial ash mass and its vertical distribution, (2) develop a model evaluation database, and (3) work with other VAACs to promote standardization of volcanic ash dispersion products. ARL will collaborate with scientists at the NESDIS Center for Satellite Applications and Research (STAR) and the U.S. Geological Survey (USGS) Volcano Hazards Program. This work should lead to more globally harmonized dispersion guidance products and a better understanding of the dispersion model capabilities.

U.S. Air Force. Through its 2nd Weather Group at Offutt AFB, NE, the Air Force provides volcanic ash surveillance and analysis for DoD aviation operations worldwide. Analysts continuously monitor all active volcanoes, generating more than 3,500 bulletins per year. In addition to alert text bulletins, USAF products include tailored satellite imagery, and graphical ash plume forecasts detailing coverage and concentration. The USAF products ensure availability of information critical to DoD aviation, particularly outside the area covered by the Washington and Anchorage VAACs and when products from other international centers are not available. Additionally, the Air Force acts as the designated back-up for the Washington VAAC.

Smithsonian Institution, Natural History Museum, Global Volcanism Program (GVP). GVP collects, catalogs, and disseminates information on ~1,540 volcanoes active in the last 10,000 years with a small staff working regular business hours Monday to Friday in the Natural History Museum in Washington, D.C. The aviation community most depends on GVP for volcano names, locations, summit elevations, and a set of unique volcano numbers (VNUM's) for precise international communication about the source of eruptive plumes and related hazards. For example, Pacaya volcano in Guatemala (along the main approach to the Capital's airport) is designated on VAAC reports as "Volcano: Pacaya 342110." The numbers, or unique portions thereof, also provide a short-hand for labeling closely spaced volcanoes on maps. Each month

GVP compiles the *Bulletin of the Global Volcanism Network* (http://volcano.si.edu/reports_bgvn.cfm) synthesizing information about volcano behavior, monitoring, and eruptions at variable time scales (months to years). The USGS and GVP jointly release the *Weekly Volcano Activity Report* summarizing eruptions and hazards during the preceding one-week interval (http://volcano.si.edu/reports_weekly.cfm). Both reports appear on the GVP website (http://www.volcano.si.edu), which also features photos, eruptive histories, and other information, including the current list of data needed by the aviation community.

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 supporting the FAA in 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.

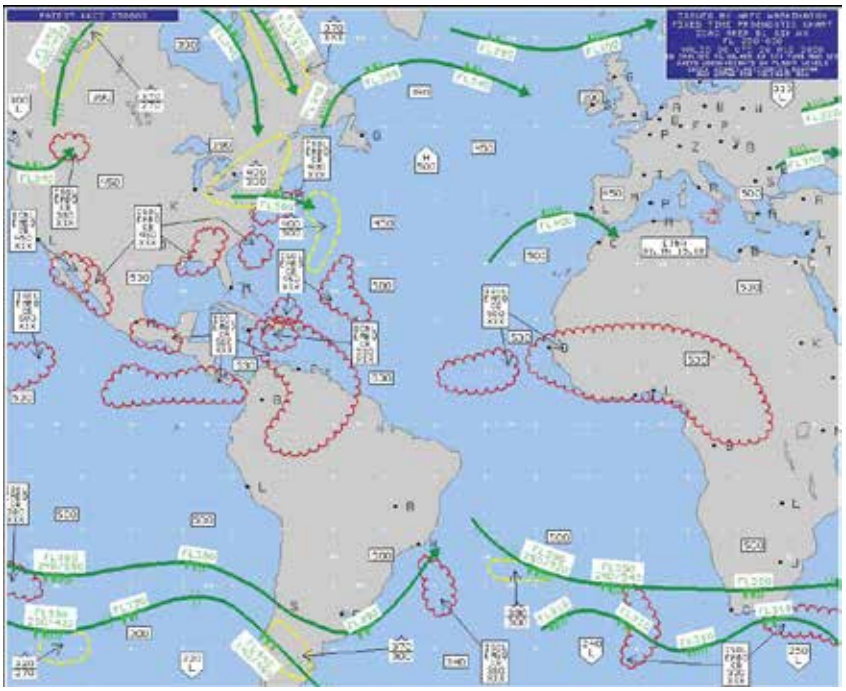


Figure 3: The Aviation Weather Center (AWC) has the responsibility, as part of the World Area Forecast Center, Washington, to provide global weather forecasts of significant weather phenomena. Presently, the AWC produces these High Level Significant Weather charts covering two thirds of the globe, both northern and southern hemispheres that are issued four times a day.

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, composed of two components of the National Centers for Environmental Prediction (NCEP): Aviation Weather Center (AWC), located in Kansas City, Missouri, and NCEP Central Operations (NCO) in College Park, Maryland. 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 made available by 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 NWS 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 disseminated by AWC via WIFS in support of the WAFS for ICAO aviation data needs and in support of World Meteorological Organization (WMO) Region IV (North America) data exchange requirements.

Under agreement with the FAA, four AWC meteorologists at the FAA Air Traffic Control System Command Center (ATCSCC) in Warrenton, Virginia, provide decision support services for strategic planning and traffic flow management for the NAS. These meteorologists work collaboratively with the AWC, the CWSUs, and with FAA planners and the aviation industry to identify and mitigate airspace constraints caused by weather, from several days out to immediate weather impacts.

Also 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 staffed 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, meteorologists 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 meteorologist, 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) up to eight times daily, with amendments as needed, for more than 660 public-use airports in the United States and its territories in the Caribbean and Pacific.

Thus NOAA, through three NWS Meteorological Watch Offices (MWO) and the two VAACs, provides large-scale, global aviation functions that can be sensibly centralized, while the NWS WFOs and CWSUs discharge local aviation functions. Additionally, NCO supplies global gridded model data of temperature, winds, and humidity twice daily for flight levels from 5,000 to 45,000 feet.

NOAA funds initiatives designed to improve the delivery of aviation weather information to NAS users. These initiatives include training programs to enhance forecaster effectiveness and development of products to improve weather information availability to the aviation community. NWS's Science and Technology Integration (STI) portfolio funds 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).

AviationWeather.gov

In addition to satisfying global requirements for aviation weather, AWC hosts AviationWeather.gov, which makes available to the aviation community text, digital, and

graphical forecasts, analyses, and observations of aviation-related weather variables. AviationWeather.gov also 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. The AWC's website infrastructure provides increased levels of data reliability for users.

Volcanic Ash Advisory Centers (VAAC)

The United States, in agreement with ICAO, operates two 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 College Park, 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.

NWS International Obligations

National Weather Service meets international commitments through participation as consultants to FAA in ICAO groups, ad hoc task forces, and project teams. In addition, NWS leads or participates in a number of WMO teams chartered by the WMO Commission on Aeronautical Meteorology. These teams include the Expert Team (ET) on Governance and Partnership (lead); the ET on Meteorological Services for Air Traffic Management (ATM) and Meteorological Information Exchange, which partners with ICAO's MARIE-PT; and the ET for Education, Training, and Competencies.

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 Federal Aviation Administration (FAA) has the responsibility to collect and distribute aviation weather data – particularly hazardous weather to operators, pilots, and air traffic control and management.

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, cloud bases and tops, as well as wind shear and microbursts. These weather sensors provide real-time information to FAA weather processing/dissemination systems 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 consist of a long range Next Generation Weather Radar (NEXRAD), Wind-Shear Detection Services (WSDS) and the Automated Surface Weather Observation Network (ASWON) portfolio programs.

Next Generation Weather Radar

Next Generation Weather Radar (NEXRAD) is a long-range weather radar system that detects, analyzes, and transmits weather information for use by the ATC System Command Center, en route, terminal and flight service facilities. NEXRAD was developed under a joint program of the Department of Commerce (DOC)/NWS, Department of Defense (DOD), and the Department of Transportation (DOT)/FAA. NEXRAD radars are national critical assets that indirectly support most weather information users in the United States. These 160 systems are long-range, Doppler weather radars that detect and produce 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. NEXRAD products and services are processed by FAA weather processing systems (discussed in next section). NEXRAD mosaics are used by en route and oceanic controllers to aid pilots in avoiding hazardous weather. The NEXRAD Dual Polarization modification project has been deployed at all sites, and software improvements to further exploit this extensive weather capability are under development.

Dual Polarization is an important upgrade to NEXRAD that improves detection of rain/snow mix, in-flight icing, hail, and non-weather biological targets (bird strike concerns). It is expected to improve the forecasting of areas where in-flight icing will occur. Working with partner agencies, the NWS is investigating whether to incorporate planned long-range NEXRAD capabilities into the NSWRC.

Several major NEXRAD system components have reached their expected service life. They will undergo a service life extension upgrade or refurbishment over the next several years to extend NEXRAD system life to at least 2030.

Wind Shear Detection Services

The Wind Shear Detection Services (WSDS) portfolio includes the Terminal Doppler Weather Radar (TDWR), the Weather System Processor (WSP), and Low-level Windshear Alert System (LLWAS). These systems automatically detect wind shear conditions near runways and approach/departure corridors and provide data to FAA weather processing systems to alert controllers, who can then warn pilots of gust fronts and wind shear in the vicinity of the airport.

WSDS Work Package 1 (WP1) will address obsolescence of the legacy WSP and LLWAS to ensure that Air Traffic Controllers will continue to receive the wind shear alerts necessary to maintain the safety of the NAS. Since these systems have been deployed, no major windshear-related incidents have occurred in the NAS.

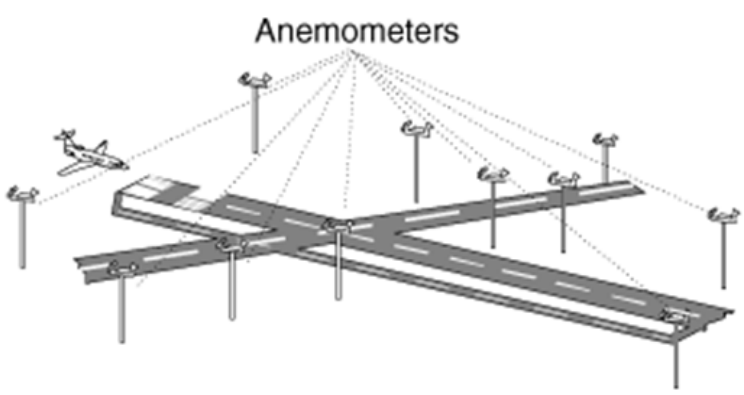
Terminal Doppler Weather Radar

The most sophisticated windshear detection system is the Terminal Doppler Weather Radar (TDWR). The primary mission of the TDWR is to enhance the safety of air travel through timely detection and reporting of hazardous weather conditions including windshear events, microburst, gust fronts, and thunderstorms in and near an airport's terminal approach and departure zones. There are 45 operational TDWRs serving 46 high-density airports with the most risk of windshear exposure. Using a three-dimensional pencil beam and fast update rate, TDWR produce detailed weather information across the entire terminal area at the surface and aloft throughout terminal airspace to controllers so they can issue warnings to pilots. TDWR weather data is transmitted to FAA automation systems. TDWR's unique products include high-resolution, rapid update of storm cells with height, precipitation, surface winds, windshear, 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).

Figure 4: A Terminal Doppler Weather Radar

Weather System Processor

The Weather System Processor (WSP)is an add-on weather processor enhancement to the Airport Surveillance Radar (ASR) Model 9 (ASR-9). The WSP was implemented as a low-cost, high-quality, wind shear detection system at medium and higher air traffic density airports not equipped with the TDWR. The WSP provides advanced Doppler weather radar performance with all the functions of the TDWR. The WSP is partitioned to the front-end radar (ASR) modification, and the back-end (WSP) development. WSP is deployed at 34 airports throughout the NAS. WSP detects and alerts on microbursts and wind shear, predicts arrival of gust fronts, and shows precipitation intensity on a graphical situation display for use by ATC without further



meteorological interpretation. Activities are underway to address sustainment of these radars and the FAA is investigating whether to incorporate the WSP into the NSWRC.

Low Level Wind Shear Alert System (LLWAS)

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 hazardous wind shear events are occurring at, or near, the runways. LLWAS interfaces with TDWR and WSP at higher density airports where the systems are co-located, or operates as a stand- alone system at other airports that do not have a TDWR or WSP. There are 49 LLWAS systems operational in the NAS today, which are undergoing service life extensions. The FAA is investigating whether to incorporate the functionality of these sensors into the NSWRC.

Automated Surface Weather Observation Network (ASWON)

The ASWON portfolio includes a numbeer of surface sensors: Automated Weather Observing System (AWOS), Automated Surface Observing Systems (ASOS), Automated Weather Sensor Systems (AWSS), Stand Alone Weather Sensing (SAWS), Digital Altimeter Setting Indicator (DASI), Wind Equipment F-Series (WEF) Wind System, and AWOS Data Acquisition System (ADAS). These sensors 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. The overall surface data they collectively provide is vital for weather forecasting. Some elements of the ASWON portfolio are undergoing a technical refresh to keep these systems operating reliably.

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 NWS forecast models that predict future weather conditions including adverse weather. A technical refresh is underway to keep these systems operating reliably. AWSS and AWOS systems will become AWOS Model-C (AWOS-C) after technology refresh is completed, and AWOS-C will be a primary surface weather sensor system along with ASOS in the NAS. As a part of on-gong technology refresh WEF and WME single wind sensor systems with C&G DASI will be replaced with the Surface Weather System (SWS). The SWS is functionally equivalent to SAWS and will be the backup surface weather observing system. At the end of current ASWON technology refresh there will be approximately 230 AWOS-C systems and 227 SWS systems in the NAS.

Digital Altimeter Setting Indicator (DASI)

The Digital Altimeter Setting Indicator (DASI) is a system that measures the atmospheric pressure and converts the measured pressure value into the actual sea level pressure based on the United States (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, so they can inform pilots of the proper setting so the aircraft's altimeter will read the correct runway elevation at touchdown. 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.

AWOS Data Acquisition System (ADAS)

The ADAS is an automation system that collects, processes, generates, disseminates, and archives various surface observation weather products from over 1100 Federal ASOS, AWOS and AWSS locations in the CONUS, Alaska and Hawaii. In addition, under the purview of the FAA's Automated Lightning Detection and Reporting System (ALDARS) contract, ADAS receives cloud-to-ground lightning strike (latitude and longitude) information for the CONUS, Hawaii and Alaska from a commercial lightning data service provider to disseminate back to the weather observing systems. In addition, this lightning data is also sent to WMSCR for subsequent dissemination to authorized FAA systems.

ADAS consists of the Sensor Control System (SCS) components located at every ARTCC and primary/secondary centralized management and control (Regional ADAS Service Processor (RASP)) components located at both Network Enterprise Management Center locations, in Salt Lake City and Atlanta. The RASP connects to every SCS over the operational Federal Telecommunications Infrastructure (FTI) network providing centralized network management and control, and it also provides the interface to the (external) commercial lightning data service provider supplying the lightning strike data to the SCS for subsequent processing

The ARTCC-based SCS provides the interface to the various types of weather observing systems in order to receive the binary-formatted One-Minute Observations (OMO), the text based Standard Hydro-meteorological Exchange Format (SHEF) and the Daily, Monthly Summary Reports. In addition, most of these systems also provide the key weather product - the Aviation Routine Weather Report (aka METAR). However, since there are over 150 legacy AWOS systems that are unable to generate the METAR, the SCS generates the METAR on their behalf.

The SCS routes these various weather products to WMSCR for dissemination to other NAS and non-NAS users. The SCS also provides network management capabilities to the local ARTCC personnel and also connects to the local Remote Monitoring and Logging System (RMLS) for status reporting. The SCS is also responsible for receiving the lightning strike information from the RASP and generating location-specific lightning activity messages to every locally-connected ASOS, AWOS and AWSS. These weather observing system include this lightning activity information into its OMO and METAR reports as well as making this information available to other local systems and through its VHF radio broadcasts. Some non-Federal AWOS are connected to WMSCR through FAA approved service providers. Only AWOS-III and IV are eligible for connection. They do not use ADAS.

Observations

Liquid Water Equivalent (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, can be more accurately determined by measuring the 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.

Weather Processing Systems

Integrated Terminal Weather System (ITWS)

ITWS generates automated weather products such as windshear alerts, gust front predictions (up to 20 minutes into future), storm cell intensity and direction of motion, terminal lightning information, detailed winds in the terminal area, and a one-hour storm forecast. ITWS receives weather data from automated surface observing sensors (ASOS and ADAS) and surrounding radars, (TDWR, ASR-9, ASR-11, and NEXRAD) and bundles it with NWS forecasts and value-added algorithms such as windshear prediction to provide real-time aviation weather information for terminal control facilities and pilots. 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

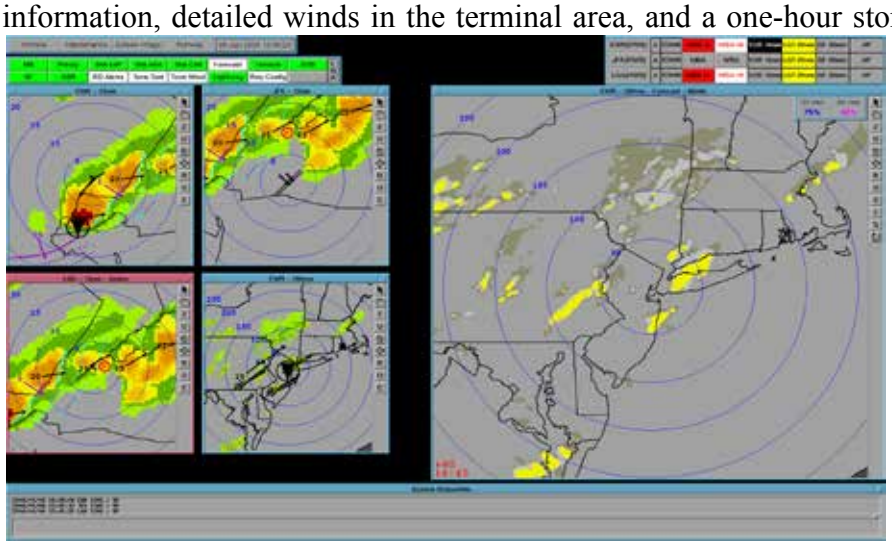


Figure 5: Example of ITWS Weather Products

the Air Traffic Control System Command Center (ATCSCC) providing common aviation weather information to 75 major airports. The FAA is targeting to implement the ITWS functionality in a 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 gathers convective weather information from radar and satellite images, blending it with NWS model data to provide an extrapolation of storm position and intensity 2 hours into the future. This process widens the common weather picture in between major metropolitan areas and expands en route weather situational awareness along busy jet-ways 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 has added a winter weather mode, convective initiation, and two-hour look-ahead aviation product to help pilots and flow managers better decide whether to fly over or around storms. The FAA is targeting to implement the CIWS functionality into the NWP.

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, NAS operators of En Route Automation Modernization (ERAM), Advanced Technologies & Oceanic Procedures (ATOP), Dynamic Ocean Tracking System (DOTS), Alaska Flight Data Processor 2000 (FDP2K), and other automation/display systems and web users. WARP serves as a one-stop source for weather interpretation by the CWSU forecasting stations. WARP sustainment activities are underway and the WARP mosaic change is targeted to complete in 2015. The FAA is targeting to incorporate WARP functionality into the Common Support Services – Weather (CSS-Wx) and the NWP.

Aviation Digital Data Service (ADDS)

The Aviation Digital Data Service (ADDS), hosted by NOAA on AviationWeather.gov, 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 the Federal Aviation Administration and the NOAA NCEP Aviation Weather Center (AWC).

The success of ADDS (averaged over 23 million hits a day in 2014) has allowed the FAA to showcase several important research initiatives, including the Current and Forecast Icing Products, 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. Operational ADDS runs at the AWC in Kansas City, MO.

Weather Message Switching Center Replacement (WMSCR)

The WMSCR system consists of two redundant servers located in the Network Enterprise Management Center (NEMC) locations in Atlanta (ATL), Georgia and Salt Lake City (SLC), Utah. These two servers operate in a primary/backup mode, where either server can provide weather and NOTAM information to all WMSCR users. These WMSCR servers connect to the NAS operational IP network and have the necessary infrastructure to support connectivity to non-NAS users via the NAS Enterprise Security Gateways. WMSCR also has deployed Service-Oriented Architecture (SOA) infrastructure to provide publication and subscription services of Pilot Report (PIREP) and Altimeter Setting reports via SWIM.

WMSCR receives, processes, and stores numerous text-formatted aviation weather products (such as Surface Observations (METARs/SPECIs), PIREPS, AIRMETs, SIGMETs, TAFs, etc.) as well as relaying the binary-formatted OMO and lightning products from ADAS, and disseminates these products to a variety of NAS and non-NAS users. WMSCR is a principal gateway to the National Weather Service (NWS), the military and foreign countries for the exchange of alphanumeric weather data.

WMSCR is also the FAA collection point for the receipt METARs sent in by authorized Non-Federal AWOS service providers for some 1000+ non-Federal AWOS locations in the CONUS, and oil platforms in the Gulf of Mexico. Note that WNSCR is a major FAA distribution system for NOTAMs from the US NOTAM System (USNS). However this service/capability will be discontinued when USNS is replaced by Federal NOTAM System (FNS). WMSCR functionality will be incorporated into a future upgrade of CSS-Wx.

Weather Camera Program

The primary goal of the FAA Aviation Weather Camera (AWC) Program is to improve aviation safety and efficiencies by providing current visual weather information in the form of near real-time video camera images to aviation users in Alaska. The camera images are designated as an FAA supplementary weather product used for enhanced situational awareness and the images are made available free on the public website at http://avcams.faa.gov. The camera images provide pilots, dispatchers and Flight Service Station Specialists with up-to-date weather conditions at airports, mountain passes, and other strategic Visual Flight Rules (VFR) locations and enables them to make better informed decisions about whether or not it is safe to fly before becoming airborne. It provides pilots with the ability to “look before you fly” as opposed to the age-old procedure “fly out to take a look”. New capability increases pilot situational awareness, enhances pilot flight decisions and when combined with other available weather information products, such as METARs, weather camera images become a powerful "go or no-go" aeronautical flight decision tool.

With the known benefits of the camera systems and the low costs of its operation there is a high level of interest to expand the service to the remainder of the NAS where shortfalls in weather related aviation safety and efficiencies are known or suspected. Past and ongoing aviation studies have identified additional safety and efficiency shortfalls in areas of the contiguous United States and Hawaii where safety and efficiency shortfalls are identified. Studies conducted by the FAA office of Aviation Safety Information Analysis and Sharing (ASIAS), and other FAA offices support the fact that weather cameras may be beneficial to aviation safety. In August 2013, the

NTSB publically recognized the safety benefits of the weather camera system in Alaska and has forwarded a request to the FAA to install and maintain camera systems in Hawaii and the contiguous United States where cameras can address identified weather-related aviation accidents and safety shortfalls.

Flight Services

Flight Services collects and disseminates aeronautical and meteorological information, providing customized pre-flight and in-flight briefings to domestic and international general aviation communities, as well as to the military and commercial air carriers throughout the contiguous United States, Hawaii, Puerto Rico, and Alaska. These services are provided by flight service specialists to pilots via phone or radio, or pilots can access the information directly through online (internet-based) web portals. Flight service specialists interpret weather and aeronautical data to provide pilot weather briefings and flight planning services tailored for a particular flight. Alternatively, pilots accessing preflight information directly through a web portal are responsible for interpreting the weather and aeronautical information for their flight.

The FAA delivers these services through the following combination of contract vehicles and automation systems: Operational and Supportability Implementation System (OASIS), Flight Services for the 21st Century (FS21), and Direct User Access Terminal Service (DUATS).

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 Joint Order (JO) 7110.10.

Flight Services for the 21st Century (FS21)

FS21 is the automation system operational at five Flight Service Stations located in CONUS operated by Lockheed Martin Corporation under the FAA's Automated Flight Service Station (AFSS) contract. The contract provides flight services to pilots throughout CONUS, Hawaii, and Puerto Rico. Lockheed Martin flight service specialists operate FS21 and are FAA-certified pilot weather briefers. FS21 provides integrated text and graphical weather products, flight planning and flight plan processing, emergency services, law enforcement, flight planning and regulatory information, and other services as defined in FAA JO 7110.10.

Direct User Access Terminal Service (DUATS)

DUATS is an internet-based weather/aeronautical information and flight plan filing service that allows pilots to access information on-line to plan a flight, file a flight plan, and perform a self-brief without the aid of a Flight Service Specialist. The FAA contracts for this service with two separate vendors: Data Transformation Corporation (DTC) and Computer Sciences Corporation (CSC). DUATS provides aviation weather in both text (alphanumeric) and graphical formats according to standards defined in FAA JO 7110.10.

Contract Weather Observer (CWO) Program

The Office of Management and Budget (OMB) created the Contract Weather Observer program in 1995, for the FAA and NWS to provide oversight and program management activities. As of October 1, 2013, NWS transferred responsibility for training oversight, certification, and facility inspection of Limited Aviation Weather Reporting Stations (LAWRS), CWOs, and non-Federal Weather Observers (NF-OBS), to the FAA. The FAA continues to provide backup and augmentation to the ASOS and the NWS provide 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 supplying operational certified CWOs to provide backup 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 LAWRS duties, which provide backup for the ASOS.

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 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 weather products of how weather will impact NAS operations. NextGen core technologies will allow introduction of new NextGen operational improvements. Efforts under NextGen include: CSS-Wx, NextGen Weather Processor (NWP), ATM-Weather Integration Concepts, and NextGen Surface Observing Capability.

Common Support Services – Weather (CSS-Wx)

In conjunction with the deployment of the System Wide Information Management (SWIM) Enterprise Service, a common information publishing capability will be deployed that will include a first offering of aviation weather information. 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. CSS-Wx extends the SWIM core services, and is being developed to enhance the collection and dissemination of aviation weather information and provide access to all users throughout the NAS. The FAA is currently in the solution development phase of the CSS-Wx program.

NextGen Weather Processor (NWP)

The NWP establishes a common weather processing platform that will enable the consolidation of the legacy FAA aviation 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 will use 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 automated objective weather constraint information by decision-makers and Decision-Support Tools (DST). The FAA is currently in the solution development phase of the NWP.

ATM-Weather Integration Concepts

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 prime concerns 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 2015 include technical studies for improvements to aviation weather information integration, transitioning an International Civil Aviation Organization (ICAO)-compliant Quality Management System (QMS) to operations, and harmonization of aviation weather requirements with the international community.

FAA 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 represents the Unites States 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.

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 addresses 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.

FAA Interagency Planning Office (IPO)

Through its 2nd Weather Group at Offutt AFB, NE, the Air Force provides volcanic ash surveillance and analysis for DoD aviation operations worldwide. Analysts continuously monitor all active volcanoes, generating more than 3,500 bulletins per year. In addition to alert text bulletins, USAF products include tailored satellite imagery, and graphical ash plume forecasts detailing coverage and concentration. The USAF products ensure availability of information critical to DoD aviation, particularly outside the area covered by the Washington and Anchorage VAACs and when products from other international centers are not available. Additionally, the Air Force acts as the designated back-up for the Washington VAAC.

FAA NextGen Office

Two principal FAA entities that report to the Assistant Administrator for NextGen are focused upon implementation of NextGen: the NAS Lifecycle Planning Division and the Aviation Weather Division (AWD) under the Office of Portfolio Management and Technology Development. The role of the NAS Lifecycle Planning Division is to ensure that the plans for the several NextGen strategic thrusts, called NextGen Portfolios, are coordinated and integrated for efficient near- and medium-term implementation across the FAA. This includes the NextGen Weather research and development as pre-implementation activities in the NAS Infrastructure Portfolio. Common Support Services-Weather (CSS-Wx), discussed earlier, is a transformational program that will address weather dissemination within the Air Navigation Service Provider infrastructure. NextGen Weather pre-implementation 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 AWD, this portfolio coordinates the investment analysis and acquisition of new weather systems and services within the FAA's Aviation Weather Services Directorate (AWSD), NOAA/NWS, and other agencies.

FAA AWG and AWSD Roles in NextGen Transition

The AWSD and AWD have important roles in the transition from today's aviation weather services to future CSS-Wx and NextGen 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 development of NAS weather requirements are 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 NAS Infrastructure portfolio.

The AWD focus on NextGen is described below and includes 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 AWD 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 NAS Infrastructure Portfolio

The NAS Infrastructure Portfolio is a planning and development portfolio that includes elements 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 NextGen weather elements: NextGen weather observation improvements and NextGen weather forecast improvements. The NextGen weather elements 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. The NextGen weather elements 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. NextGen 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 NextGen weather element, NextGen 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 NAS Infrastructure Portfolio weather elements 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.

NOAA/National Weather Service

NOAA's commitment to the NextGen initiative has two core components: NextGen IT/WebServices which will provide improved access to NOAA weather information in the formats required by NextGen users and the NextGen Weather program, which will improve the accuracy, resolution and timeliness of weather information relevant to aviation users.

Specifically, NextGen IT/Web Services will provide an information technology infrastructure which is flexible and extensible to keep pace with users' weather information needs in a rapidly changing technological environment. The greater and easier access to NOAA weather information for aviation decision-makers will facilitate better integration of this information into aviation users' decision-making processes and systems.

The NWS NextGen Weather program conducts targeted development of aviation weather tools and techniques and supports the transition of these new technologies to operations. FY15 and FY16 efforts are focused on improved data assimilation methods for advanced numerical models, evolution of statistical models for aviation weather prediction, prototyping of gridded weather information for aviation, and development of new capabilities to evaluate the performance of aviation forecasts.

NOAA aviation weather information will be available to users of the NAS and to the FAA Air Traffic Management community through the FAA's Common Support Services – Weather Program (CSS-Wx). While NextGen IT Services implements common weather data services, CSS-Wx will also implement these common data services within the FAA enterprise, and will utilize the weather data and information from NOAA for use in weather impact decisions for aviation.

Aviation Weather Testbed

The NOAA/NWS Aviation Weather Testbed is a research-to-operations facility within the NOAA National Weather Service's (NWS) National Centers for Environmental Prediction (NCEP) Aviation Weather Center (AWC). The AWT was established to facilitate the mission and realize the vision of NOAA NWS. The AWT achieves this through a physical and technical environment conducive to the efficient transfer of research into meteorological operations (or R2O). The AWT performs mission-relevant applied research and development (R&D) including R2O, and supports relevant R2O efforts of external partners in government, industry, and academia. The goal of all AWT activities is state-of-the-art meteorology, technology, and professionalism in NOAA operations.

NOAA/Office of Oceanic and Atmospheric Research

Earth System Research Laboratory (ESRL)

Within NOAA's Office of Oceanic and Atmospheric Research (OAR), the Global Systems Division of the Earth System Research Laboratory (ESRL/GSD) evaluates aviation weather impact variables such as icing, turbulence, ceiling and visibility, and convective weather and develops 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.

Plans for FY 16:

- Development of weather briefing, verification, and decision-support tools for use at Air Route Traffic Control Center Weather Service Units, the Aviation Weather Center, the Air Traffic Control System Command Center, and at Weather Forecast Offices
- Evaluate upgraded algorithms for detecting and forecasting aviation impact variables

National Severe Storms Laboratory (NSSL)

NSSL is participating in the effort to help 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. As part of this effort, the Multi-Radar, Multi-Sensor (MRMS) system is being used to support intensive research directed toward 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 rain, etc.) and data quality issues unique to FAA users. Work is also progressing on a prediction system that applies pattern recognition and geospatial data mining to forecast fields from convection-allowing ensemble prediction systems to predict the porosity of thunderstorms and thunderstorm complexes/systems. NSSL is exploring methods for using the ensemble to predict the likelihood that a region or specific flight corridor will be porous for airplane traffic.

NSSL is actively engaged in a risk reduction activity for the Multifunction Phased Array Radar (MPAR) technology with the 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 (i.e. multi-function). The NSSL has funded the development of 2 small-scale demonstrator phased array radar systems with research interests at the University of Oklahoma and MIT Lincoln Laboratory. These demonstrators will provide an evaluation of dual polarization phased array radar technologies on a planar (MIT/LL) and cylindrical platform (OU). NSSL has also begun a multi-year collaboration with the FAA to develop an Advanced Technology Demonstrator (ATD) upgrade to replace the SPY-1A passive phased array radar at the National Weather Radar Testbed (NWRT) with an active array dual polarization antenna and should be completed by FY18.

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 advanced 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. Key results have been the 2012 implementation into NWS operations of the hourly-updated Rapid Refresh (RAP) weather prediction system and the 2014 implementation of the High Resolution Rapid Refresh (HRRR) model. These systems have yielded better wind forecasts and improved diagnoses and forecasts of weather hazardous to aviation, including en-route turbulence, convective weather, in-flight icing, convection, and restricted visibility, over an expanded domain including Alaska.

Current efforts are focused on improvements to the RAP to enhance convective weather, turbulence, ceiling and visibility, and icing forecasts as well as continued improvement of the HRRR model, which provides storm-scale resolution to capture convective activity at the cell level.

Federal Aviation Administration

Aviation Weather Research Program (AWRP)

The FAA's AWRP performs applied research intended to mitigate the impact of weather on the NAS. Weather Program projects and initiatives:

- Support achievement of specific NextGen weather Operational Improvements as described in NextGen Implementation Plan.
- Mitigate weather related NAS safety and/or traffic flow efficiency issues with a line of sight to operations and existing and planned ATM systems supporting operations.
- Support the evolution of legacy weather capabilities that meet the weather information needs of today's NAS users into the capabilities that fulfill the NextGen weather vision. This work is conducted in collaboration with the FAA's designated weather provider, the National Weather Service (NWS).

The AWRP's applied research focuses on advancing the state of weather information such that it can be exploited for integration into NextGen decision-support. This advanced weather information is expected to enhance NAS safety and capacity by supporting better operational planning and decision-making by operational users including air traffic managers, flight dispatchers, and pilots. In the near and midterm, some research will support tools and methodologies used by NWS forecasters to improve the accuracy and relevancy of legacy weather products and services still mandated by FAA regulatory guidance and/or international agreement.

Service Analysis

Weather Research for Service Analysis is a critical analysis of the various technologies for translating weather information into aviation constraints, and the application of the constraints to quantify operational impacts. Major areas of work include: Conducting climatology assessments, operational impact assessments, and gap analysis to validate a potential weather issue, identify opportunities and propose workable solutions; Conducting research associated with the Air Traffic Management (ATM) Weather Integration Plan for the Next Generation Air Transportation System (NextGen); Providing critical analyses of the various technologies for translating weather information into aviation constraints, and the application of the constraints to quantify operational impacts; and determining which technologies address constraints and which address impacts. This work can be conducted as an independent assessment or as part of the New Service Needs as initial input into the Mission Analysis phase of the Acquisition Management System (AMS) lifecycle.

Observations

Advanced Weather Radar Techniques (AWRT) research focuses on monitoring and improving the quality of information derived from weather radar networks. This research has resulted in techniques for mitigating gaps in those networks to produce the Multi Radar Multi Sensor (MRMS) capability. MRMS derives information from the Weather Surveillance Radar 88D (WSR-88D), TDWR, and Canadian and Mexican weather radar networks and seamlessly integrates them into an all-weather radar network to form high resolution, three dimensional mosaics. AWRT maintains a research and development MRMS system at the William J. Hughes Technical Center (WJHTC) to conduct research into radar techniques and products that improve weather support to aviation. Current efforts include incorporation of Caribbean weather radars into MRMS, developing advanced reflectivity quality control using polarimetric radar techniques to improve the new melting layer delineation scheme, and resolving bugs found in the new MRMS operational system run by NOAA/NCEP.

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 High Resolution (CIP-HiRes) and Forecast Icing Product High Resolution (FIP-HiRes) have been developed to provide hourly updates of current and forecast in-flight icing conditions out to 18 hours. These products include probability and severity of icing conditions, as well as super-cooled large drop potential. CIP-HiRes and FIP-HiRes products are available to all NAS users on ADDS, hosted on the AviationWeather.gov site, 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 was completed in FY2011 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 accurately than those from currently used visibility tables. Results from this research are being incorporated into the development of the Terminal Area Icing Weather Information for NextGen (TAIWIN) capability. The goal of the TAIWIN effort is to develop a comprehensive terminal area ground and in-flight icing weather capability (for use by pilots, air traffic and ground de-icing operations) to provide terminal area icing weather information for operational decision-making.

Additionally research is on-going for high altitude turbine engine icing forecasts. The project is called High Ice Water Content (HIWC). The purpose of the project is to improve diagnosis and forecast of high altitude ice crystal icing in deep convective clouds which can cause temporary engine shut-down and loss of power including damage to engine compressor blades. More than 140 ice crystal engine power loss events have occurred in the last 18 years. The goal is to prevent flights from flying through areas of high ice water content.

Convective Weather

Convective weather is a critical area of research due to the considerable impact convective storms have on NAS operations. These storms contribute to delays, diversions and cancellations, along with well-documented effects on safety and capacity. The FAA's AWRP Convective Weather Research Program seeks to address this problem by: (1) Exploring how thunderstorm information is used to make decisions and assessing the need for improved dissemination and communication of this 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 are underway: (1) Improve the blending of different weather model types for prediction of convective storms in the 1-4 hour time frame; (2) Conduct an independent assessment and user evaluation on a technology to estimate radar-like precipitation intensity and echo top height of storms beyond radar range that combines global lightning data, satellite data, and output from numerical weather prediction models with existing radar mosaics; (3) Develop and advance probabilistic convective weather hazard guidance for oceanic regions from 0 – 36 hours; and (4) Identify and quantify the impacts of ramp closures due to lightning threats on NAS efficiency and safety of ground personnel, and determine if inefficiencies in lightning procedures (or the lack of procedures) can be mitigated with streamlined and consistent decision support guidance. 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, windshear, and turbulence.

Turbulence

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

Ceiling and Visibility (C&V)

Unexpected low ceilings and restricted visibility conditions are a contributing factor in over 30% of all General Aviation weather-related accidents. In addition, C&V can significantly disrupt terminal operations by degrading an airport's arrival rate and, in more severe cases, closing the airport entirely. This research is focused on developing an improved national-scale gridded analysis of ceiling and visibility conditions. These improved C&V products will take advantage of scientific advances in numerical weather modeling to provide information of conditions over data-sparse or data-void areas between instrumented airfields. This research also seeks to incorporate data harvested from satellite imagery and FAA weather cameras into the gridded forecasts. These automated, rapidly-updated C&V products will support NextGen requirements as well as provide NWS forecasters with critical information to help keep pilots safe. The FAA is working with the NWS to more effectively and efficiently integrate numerical model output and C&V algorithms into the production of NWS terminal aerodrome forecasts (TAFs) and area forecasts (FAs). Similarly, some of these advanced, automated capabilities will eventually be provided directly to Air Navigation Service Providers (ANSPs) and NAS operational decision makers. Currently, a gridded national C&V analysis (CVA) uses frequently updated C&V data from airfield observations to display C&V conditions as an automated national gridded display available via ADDS, hosted on the AviationWeather.gov site. C&V forecast information will eventually be provided hourly in both probabilistic and deterministic form to support both human users and future automated decision support systems. This research will also improve output from the Helicopter Emergency Medical Service (HEMS) display tool used in certain helicopter operations to facilitate their No-Go decisions. This year, the HEMS tool application has transitioned to NWS operations on the popular aviationweather.gov website.

Volcanic Ash

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. This task force primary mission was 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 centered in Europe, caused global disruption in the aviation community, resulting in cancelations and delays of flights.

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 an engine testing initiative 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
- Initial documentation of best practices for the VAACs

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.

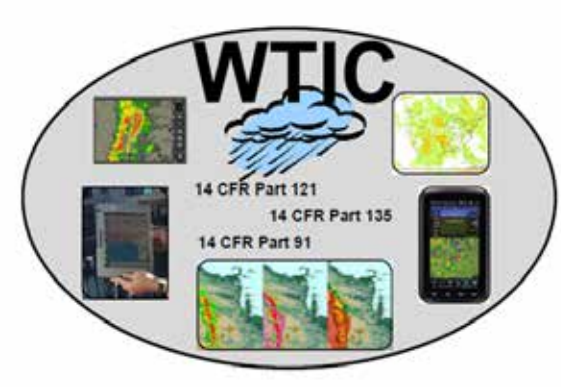
Model Development and Enhancement (MD&E)

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 advanced 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. Key results has have been the 2012 implementation into NWS operations of the hourly-updated Rapid Refresh (RAP) weather prediction system and the 2014 implementation of the High Resolution Rapid Refresh (HRRR) model. These systems have 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, as well as storm-scale resolution of convective activity at the cell level to support air traffic management decisions pertaining to convective weather.

Current efforts are focused on improvements to the RAP and HRRR to enhance convective weather, turbulence, ceiling and visibility, and icing forecasts as well as expanding to global coverage.

Weather Technology in the Cockpit (WTIC)



The purpose of this research program is to reduce the negative impacts of adverse weather conditions on the National Airspace System (NAS) and aircraft by developing, verifying, and validating recommendations to support airworthiness standards for enabling availability and improving the quality and quantity of meteorological (MET) information available to the aircraft. There are numerous research projects within the WTIC portfolio to achieve this overall project goal of recommending a [1]Minimum Weather Service that aid pilots in decision-making when faced with adverse weather conditions. The portfolio of projects will perform the research necessary to address the overarching WTIC research questions (the specific FAR Part 91 and FAR Part 121/135 research questions will be delineated below). Instrumental in gaining answers to these research questions is research to resolve any shortfalls, gaps, and issues that were identified as gaps in MET information in the cockpit. A brief summary of several WTIC research projects are detailed in the following subsections.

General Aviation(GA) Minimum Weather Service

The GA minimum weather service research effort is focused on the identification of Causal Factors for GA weather-related accidents and the gaps associated with weather information and presentation in the cockpit. The specific FAR Part 91 WTIC research will attempt to ascertain:

- Why has the weather-related accident rate for GA aircraft not decreased more with the commercial advances in MET cockpit technology and information? (i.e., obtain more insight into causes and locations of GA accidents and incidents)
- What is the minimum weather service for GA?
- What is the minimum MET information needed in the cockpit?
- What is the minimum quality of the MET information for the cockpit?
- What are the minimum rendering standards needed to enable correct interpretation of the minimum MET information in the cockpit and to enable consistent, safe, and effective decision-making?

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[1] The term "minimum weather service" as used in this document is defined as the minimum weather information content required in cockpits along with the associated parameters of that information, such as reliability, accuracy, update rates, and spatial resolution. The minimum weather service will also include rendering recommendations to reduce the likelihood of interpretation errors.

- What are the gaps and shortfalls in pilot understanding and proper use of the MET information, and what training is needed to address these gaps and shortfalls?

Research projects as part of the GA minimum weather service include defining information required to aid GA pilots in decision-making regarding adverse weather, reviewing the Aviation Safety Reporting System (ASRS) to identify and assess casual factors and trends of weather-related incidents, and conducting a causality analysis to identify, quantify, and assess gaps or issues with cockpit MET information. Additional research will include assessing the feasibility to develop agile, low latency, adverse weather cockpit alerts that require minimal cognitive processing by the pilot. The GA minimum weather service effort will also evaluate the utility of selected current MET products as decision support tools in high stress flight scenarios, and review issues associated with transition from Visual Flight Rules (VFR) into Instrument Meteorological Conditions (IMC) to determine decision making trends.

The Mobile Application project is researching MET information that provides benefits to the cockpit when presented on a mobile application. In addition, it is also researching limitations and capabilities of existing technology to support the concept of operation for this mobile application. Phase I and II of this research project was successfully completed and recommendations originating for these phases will be included as elements of the Min WxSvc.

Results from Phase II of the WTIC Standardization Assessment project indicated statistically significant variations in pilot awareness of adverse weather events. Specifically, the recognition by pilots of METARs (surface observations) changing from indicating Visual Flight Rules (VFR) conditions to Instrument Flight Rules (IFR) conditions at their destination and potential alternate airports was far below expectations. Therefore, a third phase was deemed necessary. The third phase of the WTIC Standardization Assessment project will attempt to identify the elements in the presentations (such as colors, shapes, or a combination) that contribute to the performance variations and the design of those elements that provide most consistent safe performance and adverse weather event recognition. This phase was successfully completed and the data is currently being analyzed.

The WTIC program is also 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. This research entails the development of scenario based self-study online weather training and the revision and development of pilot written exam questions.

The WTIC program works closely with multiple RTCA Special Committees to collaboratively develop standards and guidance material associated with the delivery and presentation of weather information in the cockpit. The most extensive support is provided to RTCA SC-206, Aeronautical Information Services Data Link, and their efforts to develop recommendations for data link architecture and the dissemination of MET information between aircraft and ground users. In addition, the WTIC program also provides support to RTCA SC-233 a sub-committee tasked with developing recommendations for addressing human factors/pilot interface issues for avionics.

Part 121 / 135 Minimum Weather Service

The Flight Deck Information research of the WTIC Minimum Weather Service for aircraft operating under FAR Part 121/135 research will attempt to ascertain:

- What are the current operational inefficiencies, by phase of flight, attributable to shortfalls of MET information in the cockpit?
- What are the potential NextGen operational inefficiencies attributable to shortfalls of MET information in the cockpit?
- What is the minimum weather service* for major aircraft categories in Part 121 and 135?

This WTIC Flight Deck Information research project includes research to provide accurate and timely wind information to flight management systems (FMSs), and quantify any predicted benefits of associated NextGen application programs (e.g., TBO, CLEEN, Interval Management). In addition, this minimum weather service effort will examine methods designed to improve characteristics of MET information such as format, latency, accuracy, etc., so that the information is ready for direct integration into select decision support tools (DSTs).

The WTIC program In Situ Turbulence project goal is the successful integration of objective turbulence information into NAS operations, both during the strategic flight planning process as well as the tactical process of re-routing aircraft during flight. The intent here is to provide the cockpit with current and forecast turbulence information in order to permit the pilot to be a more informed decision maker in terms of flight planning and cabin management. In order to achieve this goal the WTIC program will support the expanded deployment of the EDR algorithm throughout the airline industry (through government funded efforts and advocacy) in order to support meeting the required density of turbulence observations to support NextGen.

A separate effort, the Weather Technology in the Cockpit (WTIC) Turbulence/EDR Uplink Demonstration, assessed 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. A Quantification of Benefits to the NAS was conducted as part of this effort. Current efforts include demonstrating the capability to uplink tactical turbulence and cloud top information to the cockpit. A new turbulence forecast product is planned to be operational that will add explicit forecasts for mountain-wave turbulence and extend current capabilities to all level, surface to FL450.

The WTIC program MET Information in Oceanic and Remote Regions Shortfall Analyses project will identify current operational inefficiencies, potential NextGen operational inefficiencies, and potential safety risks (current and NextGen) attributable to gaps of MET information in the cockpit in oceanic and other remote regions. The results of the research will partly address the WTIC research question of identifying current operational and NextGen inefficiencies attributable to gaps of MET information or technology in the cockpit. Previously accomplished WTIC research indicated benefits to providing cloud top information in oceanic and remote regions. This research is intended to identify gaps that are not fully resolved by providing cloud top information in the cockpit. A Human over the Loop Demonstration (HOTL) to assess the impacts to decision making in a collaborative environment of providing cloud top data in oceanic and data sparse areas was successfully completed and planning has commenced for an oceanic demonstration that will include other oceanic Min WxSvc recommendations.

The WTIC program Adverse Weather Alerting Functions Use Case Analysis will identify Use Cases where a weather alerting function may address a weather information gap or assist in pilot decision-making relative to an adverse weather condition along their intended route of flight. The research will also include analyses to determine the concepts of an alerting function with performance characteristics that could provide benefit to pilots. The deliverables from this research will be used by the WTIC program to select the weather alerting functions to be prototyped and evaluated in a flight simulation demonstration. The first human-over-the-loop (HOTL) simulation to assess the end-to-end system component compatibility of generating a tactical turbulence alert to the cockpit crew was successfully completed and the result indicates that the latency was acceptable. HOTL II which assesses the effectiveness of alert information in aiding pilot decision making for cabin management will commence shortly.

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.

CLIMATE SERVICES

For the 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

National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) provides climate services through the National Centers for Environmental Prediction's (NCEP) Climate Prediction Center (CPC), the NWS Climate Services Branch (CSB), and more than 150 NWS regional and local offices nationwide. The NWS Climate Services Branch (CSB) provides programmatic support to CPC and NWS local offices. In collaboration with other NOAA offices, CSB develops training, education and outreach materials. CSB designs climate data mining and analysis tools, as well as local climate products for users of climate information. CSD fosters climate services ties with other NOAA offices, federal government agencies, academia and external climate communities.

CPC delivers a broad range of products and services including climate monitoring and forecasts, as well as regional climate impacts information. The 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 also identifies the important physical factors responsible for variability, anomalies, and trends in global and regional climate in order to improve these products. The NWS Weather Forecast Offices (WFOs) use these products to deliver climate services to local users. Together with NWS regional offices WFOs are responsible 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 in agriculture, energy, transportation, water resources, and health. 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 Centers for Environmental Information/Center for Weather and Climate *formerly known as the National Climatic Data Center (NCDC)*

The National Centers for Environmental Information (NCEI, see www.ncei.noaa.gov), Center for Weather and Climate (CWC) is the trusted authority for U.S. and global retrospective weather and climate data and related environmental information. CWC provides the nation with environmental intelligence for decision-making through use-inspired applied science, the resulting products and services, and authoritative assessments and monitoring. Science at CWC is peer-reviewed, applied research that transforms data into authoritative, accessible, and actionable information. CWC's product lines and services reflect the needs of customers representing the breadth of economic sectors for important regional, national, and global areas.

CWC operates a reference surface observing network, sustains baseline historical data records that incorporate satellite and surface observations, and actively contributes to climate and weather monitoring and assessment efforts of national and international significance. Environmental information—from the stone age to the space age, e.g., from paleoclimate data to present *in situ*, atmospheric, ocean, and satellite data—are the basis for the CWC's sustained science and services commitment to all users.

The State of the Climate in 2014 Report. The "State of the Climate" (http://www.ncdc.noaa.gov/bams-state-of-the-climate/) series has provided a detailed update on global climate indicators, notable weather events, and data collected by environmental monitoring stations and instruments since the report's inception in 1990. For the 15th consecutive year, CWC (formerly known as the National Climatic Data Center, or NCDC) scientists served as lead editors of the report, which was compiled by 420 scientists from 58 countries across the globe and published as a supplement to the *Bulletin of the American Meteorological Society*. For the third year, the report was accompanied by an online rollout at https://www.climate.gov/news-features/understanding-climate/2014-state-climate-highlights, providing easy access to key themes of the report for the public.

The report used dozens of internationally recognized climate indicators to track and identify changes and trends in the global climate system. Each indicator included thousands of measurements from multiple independent datasets. The diverse array of international authors helped consolidate this wide range of data, using their expertise to more fully understand and communicate the state of the complex climate system. The report provided a valuable reference for the increasing number of professionals and consultants who use climate conditions and trends in their work.

NCEI Website and Home Page. NCEI developed an integrated website landing page from the previous NOAA Data Centers and redesigned components of the previous NOAA Data Centers websites by simplifying access to systems, data, and services. In addition, more efficient maintenance was implemented and Google Analytics was introduced to better analyze website traffic and anticipate customer needs. This enhanced redesign now allows better navigation for major topical areas, including data access and information, as well as streamlines content and data access systems into logical groupings. Customers are now able to easily gather pertinent data and information for their needs and operations. Additional benefits from this redesign

include simplified hardware and software support, enhanced security, and better use of personnel resources by streamlining maintenance.

Reference Environmental Data Records (REDR) Program. Formerly the Climate Data Records (CDR) Program, REDR transforms use-inspired science research results into operational products in order to meet the growing needs of U.S. industry and commerce. The REDR Program has amplified the investment of hundreds of millions of federal research dollars spent at other agencies, particularly NASA, by transitioning the Nation's best, most mature research to NOAA operations. The REDR Program's accurate determination of environmental trends helps the Nation to better estimate the magnitude and impact of future changes.

- The REDR Program generates and sustains a portfolio of operational satellite and *in situ* REDRs that are required for operational decision-making, environmental and climate policy development, catastrophic risk assessment, and national, state, and regional climate assessment and information products.
- The REDR Program provides continuing return on investments past the lifetime of major NOAA observing investments, including satellites such as POES, GOES, JPSS and future GOES-R instruments.

Record-Setting Volumes of Data. NCEI archives data to preserve them for posterity from every corner of the globe, including land-based, marine, model, radar, weather balloon, satellite, and paleoclimate data. CWC routinely incorporates, stewards, and provides access to these data to meet the needs of a wide variety of customers. In 2014, NCEI planned for vast increases in data requests, implemented new archival storage and access practices to reduce the cost of archive and delivery of data, and made improvements to the information technology infrastructure to proficiently handle increases in data delivery. NCEI upgraded the system used to retrieve data from the digital archives in order to improve efficiency and reduce data delivery times for radar and satellite orders. For more information, see NCEI's Data Access page, http://www.ncdc.noaa.gov/data-access.

Throughout FY 2014, users from all over the world downloaded NCDC's model, satellite, and radar data from both the Asheville, NC, and Boulder, CO, sites—totaling a record volume of over 6 petabytes. For perspective, one petabyte of data is equivalent to the digital space needed for over 13 years of high-definition television. Satellite data access had the highest volume of data downloaded, followed by model and radar data.

Alaska Climate Division Data. NCEI scientists and climate services professionals worked with stakeholders in Alaska to identify, define, and implement 13 climate divisions within Alaska. These climate divisions are now serviced by near-real-time climate data, with a record that extends back to 1925. Alaska's near-real-time climate-division data services are now on par with those for the contiguous United States. The establishment of these divisions will allow for an expanded suite of prediction services from NOAA's Climate Prediction Center.

U.S. Climate Reference Network (USCRN) Expansion in the State of Alaska. The USCRN Program, managed by NCEI, has been working to expand the network in Alaska since 2009. As of the end of 2014, a total of 16 stations have been installed and are operating across Alaska. During summer 2015, two new sites will be installed in the Denali National Park and Preserve and in the Selawik National Wildlife Refuge, bringing the total number of operational sites in

Alaska to 18. The plan is to install a total of 29 USCRN stations in Alaska by the end of 2022. Data from the USCRN stations in Alaska, as well as the 114 stations in the lower 48 states, and two in Hawaii, are available at http://www.ncdc.noaa.gov/crn/.

Regional Climate Services. The Regional Climate Services (RCS) program focuses on defining requirements and developing products, services, and information access services for a broad range of users across the Nation. These efforts are supported by six Regional Climate Service Directors (RCSDs) in the six NWS Regional areas. The RCSDs assess the needs of public and private sector users at the local, state, regional, and federal levels and leverage the work of CWC, as well as the Center for Coasts, Oceans, and Geophysics' (CCOG) coastal data development activities to ensure broad, national, comprehensive data and information for issues related to the interaction of land and coastal physical, biological, and chemical processes.

- The six RCSDs work closely with six independent, public-private sector Regional Climate Centers (RCCs) that focus on addressing local, state, and regional climate services and issues. Each RCC is located on a university campus, receives NOAA funding for a portion of their operations, and provides a range of services and products to NOAA, state and local agencies, businesses, and other stakeholders.

NOAA/Office of Marine and Aviation Operations

***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.

The *Ronald H. Brown* typically supports research programs of NOAA's Tropical Atmosphere-Ocean (TAO, http://www.pmel.noaa.gov/tao/) Project (real-time data from moored ocean buoys for improved detection, understanding and prediction of El Niño and La Niña). The primary objective for the ship is servicing some of the 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.

Ronald H. Brown conducts the PIRATA Northeast Extension (PNE; http://www.aoml.noaa.gov/phod/pne/index.php) 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. The ship will also be conducting the CalWater 2 project in the Pacific. The goal of this work is to develop and test methods to improve U. S. West Coast forecasts of damaging landfalling winter storms emerging from the data sparse Pacific Ocean. The project will involve multiple air and sea research platforms.

The WP-3D, G-IV, and DHC-6 aircraft will take part in several projects for the Office of Oceanic and Atmospheric research. In January, the G-IV will conduct the CalWater 2016 project

studying high-altitude winds via NOAA airborne radar with the goal of improved weather and air-quality forecasts. During the summer, the DHC-6 Twin Otter aircraft will conduct a BioLidar mission in the Gulf of Mexico region. This mission will use an aerosol sensor and a Doppler Lidar to understand how atmospheric particles can influence weather and climate via cloud production, precipitation, and light scattering with the goal of improved understanding atmospheric chemistry. One of NOAA's other DHC-6 aircraft with conduct the Arctic Heat project in Alaska during June and July. This project will help increase understanding of the complex processes that produce variability in the Arctic ecosystem with the goal of improvements in weather and sea-ice forecasting.

United States Air Force

The USAF, through 14th Weather Squadron (14 WS), provides centralized climatology services and produces specialized weather-effects information for the DoD, Intelligence Community, and allied nations. The 14 WS provides decision-enabling products, allowing DoD command authorities to anticipate and thus exploit environmental impacts on all aspects of military operations worldwide and enhances the combat capability of the United States by delivering climate-based environmental situational awareness to the USAF, the Army, Unified Combatant Commands, the Intelligence Community, and the Department of Defense. The squadron produces a suite of standard and tailored products such as Operational Climatic Data Summaries, Engineering Weather Data, Wind Roses, and Wind Stratified Conditional Climatologies, among others, and provides frequency of occurrence and duration for mission-limiting factors. In addition to climatology products, the 14 WS provides forensic weather research, climate analysis, and climate monitoring and prediction. The squadron continues to modernize an online climatology toolkit by integrating GIS visualizations on its website and developing GIS-based spatial and cloud climatologies. These technologies provide DoD decision-makers with the data needed to optimally plan and execute operations.

Long-range outlook products cover time periods from one to six months into the future, and include seasonal forecasts and hazard assessments. The USAF produces 6-month graphical 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. The USAF is enhancing its 6-month outlook production capability by leveraging research conducted by the Air Force along with 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) in order to provide planners with a risk management tool to assess effects on future operations.

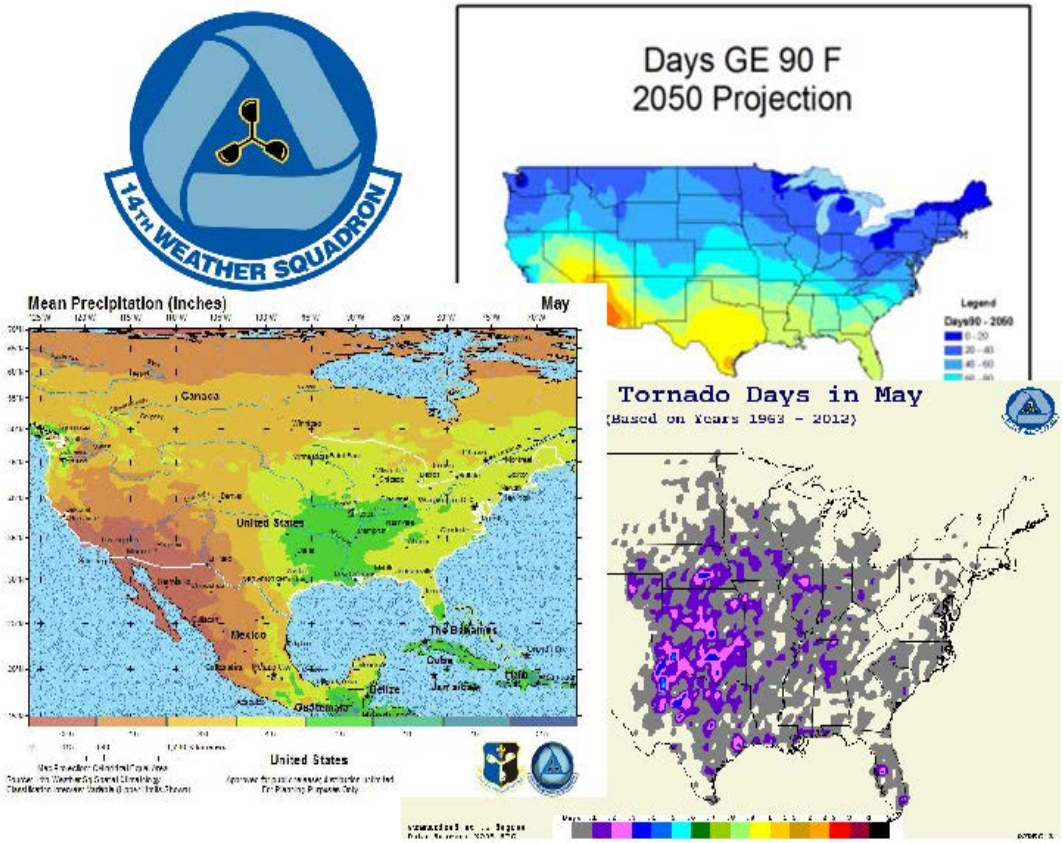

Figure 1: The 14th Weather Squadron collects and analyzes climate data and information, providing tailored climatology services to DoD, the Intelligence Community and allied nations. These regional climate products help the end-user assess and mitigate future operational impacts

United States Navy

Rear Admiral Jonathan White is also the Director of Task Force Climate Change. In order to establish capabilities in accordance with the Arctic Roadmap, special equipment and possibly new ice capable survey vessels and/or Polar Icebreaker (PIB) ships will be needed. In 1965 the Navy turned over all ice breaking responsibilities to the Coast Guard. The Navy supports the Coast Guard in their requirements, and it makes good sense to have a modern, dedicated Arctic icebreaker to assist with disaster response and search and rescue. But at this point, we don't expect Navy ships to be operating in the ice zone. Our interest in the Arctic has been spurred by the fact that there is increasingly open water there, and that is where we will most likely be operating. The breaking up of the Arctic sea ice means that the ice is more subject to winds and currents, so it is certainly conceivable that a ship operating in open waters could quickly find itself surrounded by sea ice. Having a more reliable Arctic model and more accurate sea ice forecast would make it much safer for surface ships to operate there.

In February 2015 the U.S. Navy issued an Implementation Plan to further strategic planning to increase operational capabilities and infrastructure in the Arctic, consistent with the U.S. Navy Arctic Roadmap 2014 - 2030. The United States assumed chairmanship of the Arctic Council in

June 2015. Within the next decade, it will be operating routinely in the Arctic with an appropriate presence that includes more than just submarines. Navy's global area of responsibility is growing as it adds new coastlines and a new ocean. With the fiscal challenges confronting the Navy, it must use cooperative multilateral partnerships to successfully build an Arctic-capable force.

Navy is investing in significant Arctic research. It is important that it improve its understanding of the environment for safety of operations, because the Arctic will remain a harsh and challenging environment even as it becomes more accessible and active. This line of effort includes an emphasis on research to better understand the changing climate and improve Arctic weather forecast capabilities, and on high resolution surveying of the seabed.

The U.S. federal fleet currently has two icebreakers, USCGC Polar Star, has been refitted, extending its operational life by perhaps another decade. The U.S. also has one medium icebreaker, the USCGC Healy, which is around 15 years old and is currently dedicated to scientific missions. Ice-hardening ships is expensive and impacts ship capabilities, like speed and turn-radius. We are still trying to determine the need for ice-hardened hulls.

The White House released a new National Strategy for the Arctic Region on 10 May 2013 reflecting a growing recognition that the Arctic is opening up for human enterprise and will increasingly become a strategic priority for the United States. The Office of Science and Technology Policy (OSTP) is leading the effort considering the larger policy issues associated with national requirements for icebreaking services in both poles. The Science and Technology Policy Institute is summarizing past reports and seeking updates from key Federal agencies including the USCG, NSF, NOAA, NASA, and DOT.

The Naval Meteorology and Oceanography Command has assets that can assist in this national effort. The command manages a fleet of six world-class ocean survey vessels and operates some of the world's finest oceanographic analysis and prediction computer models. Navy also partners with the National Oceanic and Atmospheric Administration and the U.S. Coast Guard to monitor polar ice movement at the National Naval Ice Center in Suitland, MD. This is in line with the National Arctic Strategy's third line of effort—building and maintaining cooperative relations with other Federal Agencies, as well as with Arctic nations and allies.

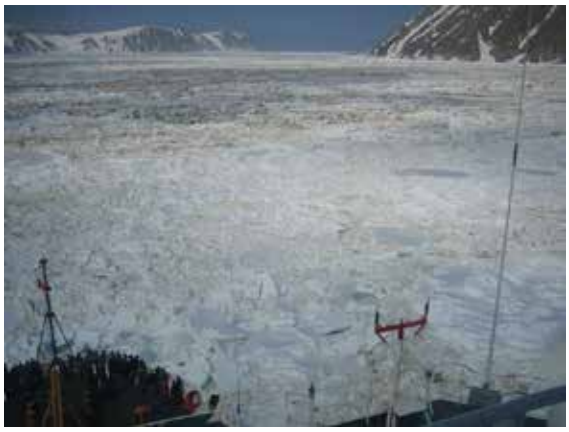

Figure 2: Passing through the Bering Strait on a USCG Icebreaker

RADM White believes the presence of well-meaning naval forces acts as a stabilizing influence toward mutual prosperity and safe maritime activity. Climate change and energy are two key issues that will play a significant role in shaping the futures security environment. Working closely with U.S. departments and agencies, the Department of Defense has undertaken environmental security cooperative initiatives with foreign militaries that represent a way of building trust through sharing best practices on installations management and operations.

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 almost three 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.

Figure 3: The IPCC's Fifth Assessment Report is comprised of the contributions from the three working groups: (1) The Physical Science Basis (Sept 2013, http://climatechange2013.org/); (2) Impacts, Adaptation & Vulnerability (Mar 2014, http://ipcc-wg2.gov/AR5/report/); and (3) Mitigation (Apr 2014, http://mitigation2014.org), as well as a Synthesis Report that will be released in Oct 2014.

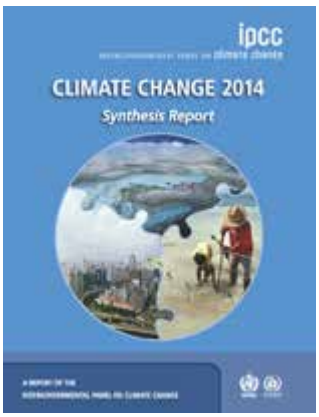

Figure 4: The IPCC's Fifth Assessment Report is comprised of the contributions from the three Working Groups (1) The Physical Science Basis [Sept 2013], (2) Impacts, Adaptation & Vulnerability – released in two volumes [Mar 2014], (3) Mitigation [Apr 2014], and (4) Synthesis Report [Oct 2014].

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, adaptation and vulnerability, and (3) mitigation. In 2013-14, the IPCC completed its Fifth Assessment Report, which is comprised of the three working group contributions listed above, as well as a Synthesis Report [see image]. 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).

On the climate services front, the State Department supports the work being led by NOAA colleagues to ensure that the WMO's Global Framework for Climate Services (GFCS) gets set-up smoothly and provides real value-added to the climate service domain.

In addition to its primary role in the organizations listed above, DOS is active in several relevant Federal interagency processes, including the Committee on Environment and Natural Resources and Sustainability

(CENRS) of the National Science and Technology Council, the Subcommittee on Global Change Research (SGCR) and the broader U.S. Global Change Research Program (USGCRP), several of its interagency Working Groups, as well as US Group on Earth Observations (USGEO) subcommittee and its interagency International Working Group. The CENRS 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 (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 security, disaster warnings and assistance, WMO (including the recently launched Global Framework for Climate Services) and UNEP activities (including the Climate and Clean Air Coalition), and international meteorological and Earth observing programs. More information available at http://www.ipcc.ch/report/ar5/syr/

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

Interagency Collaborative Research Programs and Projects

U.S. Global Change Research Program (USGCRP)

The U.S. Global Change Research Program (USGCRP, http://www.globalchange.gov/agencies) is a Federal program mandated by Congress that coordinates and integrates global change research across 13 Federal agencies to most effectively and efficiently serve the Nation and the world. Through interagency partnerships and collaborations with leading experts, USGCRP works to advance climate science and improve the understanding of how global change is impacting society, both today and into the future.

The vision laid out in USGCRP's *National Global Change Research Plan 2012–2021: A Strategic Plan for the U.S. Global Change Research Program* (http://www.globalchange.gov/browse/reports/national-global-change-research-plan-2012%E2%80%932021-strategic-plan-us-global-change "the 2012–2021 Strategic Plan") maintains a clear emphasis on advancing global change science, but it also calls for a strengthened focus on ensuring USGCRP science informs real-world decisions and actions. USGCRP's four strategic goals are to:

1. **Advance Science** - Advance scientific knowledge of the integrated natural and human components of the Earth system to understand climate and global change.
2. **Inform Decisions** - Provide the scientific basis to inform and enable timely decisions on adaptation and mitigation.
3. **Conduct Sustained Assessments** - Build sustained assessment capacity that improves the Nation's ability to understand, anticipate, and respond to global change impacts and vulnerabilities.
4. **Communicate and Educate** - Advance communication and education to broaden public understanding of global change and develop the scientific workforce of the future.

For more information, please refer to http://www.globalchange.gov/

NOAA/NESDIS

National Centers for Environmental Information/Center for Weather and Climate *formerly known as the National Climatic Data Center (NCDC)*

Explaining Extreme Events of 2014 from a Climate Perspective. For the fourth year, CWC scientists are collaborating with their colleagues across the globe to examine the causes of certain extreme weather and climate events. Scientists from CWC served as part of the team of lead editors for the report, entitled "Explaining Extreme Events from a Climate Perspective" and published as a supplement to the Bulletin of the American Meteorological Society. The report continues to grow, and this year 34 different research teams from around the world contributed to the peer-reviewed report that examined the causes of 30 extreme events that occurred on all seven continents during 2014. In addition to investigating the causes of these extreme events, these reports include multiple analyses of a single event, allowing scientists to compare and contrast the strengths and weaknesses of their various analytic methods. Despite the different strategies, there was considerable agreement between the assessments of the same events, especially for heatwaves. By further developing the ability to put extreme weather and climate events into the longer-term context of climate change, NCEI is helping provide the public with the information needed to make decisions about effectively minimizing and preparing for the impacts of these events.

An Independent Record of Global Warming. In collaboration with researchers from the University of South Carolina, the University of Colorado, and the University of Bern in Switzerland, NCEI developed a compilation of temperature records based on data from ice cores, corals, and lake sediment layers that revealed a pattern of global warming from 1880 to 1995 comparable to the global warming trend recorded by thermometers. While the thermometer-based global surface temperature record provides meaningful evidence of global warming over the past century, it is critical to have independent analyses to verify that record, because it can be affected by such things as land-use changes, shifts in station locations, and variations in instrumentation. For this analysis, the team used environmentally sensitive proxies to compile a temperature record spanning 130 years that is independent from thermometer-based records. The research, which was detailed in "Global Warming in an Independent Record of the Past 130 Years,"(http://www.ncdc.noaa.gov/news/independent-evidence-confirms-global-warming-instrument-record) published in *Geophysical Research Letters*, resolved some of the uncertainty associated with thermometer records.

Regional Surface Temperatures for Six Continents and the Arctic. NCEI scientists helped construct a one-of-a-kind synthesis and analysis of temperatures over the last 2,000 years for six different continents and the Arctic. This effort is part of a large international effort under the auspices of the Past Global Changes Programme of the International Geosphere-Biosphere Programme. These reconstructions cover the last millennium on annual-to-decadal timescales and extend into the first millennium of the Common Era, which began in 1 A.D., on annual-to-multi-decadal timescales. To date, scientists have produced 2,000 year-long annual-to-decadal temperature time series for the hemispheres and the globe, but not at the continental scale.

For this project, NCEI scientists served as group leaders for the North American regional reconstruction and as part of the core writing team for the highly cited paper, "Continental-scale temperature variability during the last two millennia" in *Nature Geoscience*. NCEI also served as

the data hub for the entire effort, producing state-of-the-art proxy and reconstruction datasets for the Common Era. Overall, this effort greatly extended the record of past climate and explicitly characterized uncertainties in the reconstructions. With these data, scientists will be able to better understand extremes in annual to decadal temperature fluctuations over the past 2,000 years in a way that is not possible using the instrumental record alone.

National Centers for Environmental Information / Center for Coasts, Oceans, and Geophysics

Sea Surface Temperature Datasets. The Niño 3.4 index is an important measure of El Niño Southern Oscillation (ENSO) conditions, which NOAA's Climate Prediction Center uses to support ENSO monitoring and forecasting. The Niño 3.4 index is calculated based on two NCEI datasets: the Optimum Interpolation Sea Surface Temperature (OISST, http://www.ncdc.noaa.gov/sst/) dataset and the Extended Reconstructed Sea Surface Temperature (ERSST, https://www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst-v3b) dataset. In 2013, scientists found that monthly Niño 3.4 indices calculated from the two datasets differed by as much as 0.5°C in some ENSO events. Such large differences complicate the monitoring and prediction of current and future ENSO conditions, so NCEI scientists analyzed the datasets and computational methods of the index to identify the causes of the differences.

NCEI completed several experiments on the data involving the integration of satellite observations into ERSST and the analysis of bias adjustment methodologies in both OISST and ERSST. These analyses found that the major cause of the difference was the bias adjustment applied to the satellite sea surface temperature measurements used to produce the OISST dataset. By accounting for these differences, NCEI not only verified the quality of the data analyses, but also provided an objective basis for users to select the appropriate sea surface temperature product.

Pathfinder Sea Surface Temperature (PSST, http://www.nodc.noaa.gov/SatelliteData/pathfinder4km/) is a high-resolution, long time series of satellite sea surface temperature data. This operational reference environmental data record (REDR) is a primary source of information for numerous regional and global marine resource efforts, e.g., applications such as coral reef stress monitoring, local habitat characterization, as well as basic physical oceanographic work. The PSST REDR is recognized and utilized by the community as an authoritative source of information.

World Ocean Atlas. NCEI scientists have worked to construct the World Ocean Atlas, which contains objectively analyzed climatological fields of *in situ* temperature, salinity, oxygen, and other measured variables at standard depth levels for various compositing periods for the world ocean. Regional climatologies (https://www.nodc.noaa.gov/OC5/regional_climate/) for the Greenland, Iceland, and Norwegian Seas, the Nordic Seas and Northern North Atlantic, the Arctic, the East Asian Seas, and the Gulf of Mexico, were created from the Atlas, providing a set of high resolution mean fields for temperature and salinity.

NOAA/Office of Oceanic and Atmospheric Research (OAR)

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.noaa.gov/climate.html

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 NOAA line offices, 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 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 Laboratories and Programs

Atlantic Oceanographic and Meteorological Laboratory (AOML)

AOML conducts mission oriented scientific research that seeks to understand the physical, chemical, and biological characteristics and processes of the ocean and atmosphere, both separately and as a coupled system. The Laboratory's research theme related to oceans and climate includes interdisciplinary scientific investigations of the physics of ocean currents and water properties, and on the role of the ocean in climate, extreme weather events, and ecosystems. The tools used to carry out these studies range from sensors on deep ocean moorings to satellite-based instruments to measurements made on research and commercial shipping vessels and autonomous vehicles, and include data analysis and numerical modeling as well as theoretical approaches. This includes stewardship of oceanic measurements relevant for climate, including custodianship of major data sets, development and deployment of new sampling methods, new analysis tools, and carrying out long-term consistent environmental measuring programs.

In an effort to better understand and forecast climate, the Atlantic Oceanographic and Meteorological Laboratory (AOML) contributes to the maintenance of the global Argo program (a global array of 3,000 vertically profiling floats), the global drifter program (which maintains a global array of more than 1500 surface drifters), the expendable bathythermograph program (the deploys more than 8000 XBTs each year and processes more than 14,000 XBTs each year). AOML collaborates with the Pacific Marine Environmental Laboratory (PMEL) 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 (e.g. Global Repeat Hydrographic/CO2/Tracer (GO-SHIP) surveys in Support of CLIVAR and Global Carbon Cycle objectives: Carbon Inventories and Fluxes program). In addition AOML maintains time series observations of the Florida Current and Deep Western Boundary Current (Western Boundary Time Series program) and the Deep Western Boundary Current in the South Atlantic (the Southwest Atlantic Meridional Overturning Circulation Array); these programs contribute to the national and international programs designed to measure the meridional overturning circulation in the Atlantic Ocean which is the large scale ocean circulation that redistributes heat, fresh water and carbon north and south in the ocean. AOML manages these observational programs and conducts ocean circulation research on data collected through them. All of these programs are major contributors to the World Climate Research Programme's Climate Variability and Predictability (CLIVAR) Experiment and the Global Ocean Data Assimilation Experiment. Combined with satellites, these data provide a quantitative description of the changing state of the ocean and the patterns of ocean climate variability from months to decades, including heat, freshwater and carbon storage and transport.

In FY15, AOML plans to increase understanding of the ocean's role in climate through the stewardship of long term ocean observations, analysis of observations and models and numerical simulation of ocean circulation induced changes to climate. For example, the Physical Oceanography Division (PHOD) of AOML will continue to show that the variation of surface and subsurface ocean temperature and salinity is important to and linked with the Atlantic meridional overturning circulation (AMOC), hurricane intensification and fisheries productivity on climate time scales.

Air Resources Laboratory (ARL)

To provide a sound scientific basis for understanding climate variability and change, the Air Resources Laboratory (ARL) contributes to two land-based reference observing networks: the U.S. Climate Reference Network (measuring surface climate variables) and the Surface Energy Budget Network, and to the Global Climate Observing System Reference Upper-Air Network (GRUAN).

ARL also provides analyses of variability and change in the boundary layer, free troposphere and stratosphere, with an emphasis on atmospheric temperature, stability, and circulation and on clouds. ARL has long-standing and internationally-recognized expertise using radiosonde observations, often combined with satellite observations or climate model results, to understand global upper-airchanges on diurnal to multi-decadal time scales. In addition, ARL has developed long-term datasets using model analysis and observed rainfall for air stagnation, and merged in-situ data and satellite observations for dust storm climatology.

In FY16, ARL will:

- Continue to provide maintenance and testing of existing technologies at the climate reference networks and evaluate new technologies;
- Examine the impact of extreme events, such as a late spring freeze and mid-summer droughts, on the seasonal energy budgets of carbon and water in eastern hardwood deciduous forests.
- Continue to provide leadership for guiding the full implementation of the GRUAN;
- Continue using radiosonde observations to evaluate models of the global carbon cycle and to evaluate other observational approaches to identify boundary layer structures and variations;

Continue analysis of the variability and trends in the climate system, interactions between climate and air chemistry, and the performance of operational and research models.

Climate Program Office (CPO)

CPO manages a climate observations program and NOAA's largest competitive research program that funds high-priority science to achieve its mission to advance scientific understanding, monitoring, and prediction of climate and its impacts to enable effective decisions. CPO's position at the intersection of the climate research, observation, monitoring, modeling, and decision science communities enables it to lead a balanced, mission-driven research agenda and forge partnerships that enhance society's ability to manage risks, enhance resilience, and adapt to a changing climate. CPO provides strategic guidance and coordination of NOAA's climate science and services programs, and integrates them with the efforts of NOAA laboratories and external communities.

CPO also supports multi-disciplinary research and assessments that help communities better plan and respond to climate change and variability. CPO-supported research is conducted in regions across the United States, at national and international scales, and globally.

One of CPO's core missions is to develop and sustain a global in situ climate observing system with partners such as AOML, PMEL, and NESDIS NOAA's instruments are a vital part of an international system to monitor Earth's climate and provide data for NOAA research, modeling, predictions, and forecasts. CPO leverages climate science capacity and capabilities to provide Americans with critically needed early warning systems that are timely and relevant for stakeholders at a range of scales spatially (local to global) and over time (weeks to decades) and include the effects of changing climate conditions on extreme weather events.

CPO will continue to support modeling, research, analysis, and data collection aimed at gaining a better understanding of climate processes. These activities are essential steps toward delivering climate prediction and assessment products for risk management and decision-making. CPO will also sustain grant programs that advance the knowledge and capacity of decision makers to assess risk, prepare for, and respond to the impacts of climate variability and change.

FY 16 Plans:

- Execute the OAR-NWS MOU that establishes a strategy between NWS and OAR to ensure NOAA meets the growing societal demand for climate information through improved modeling and predictions as well as development of applications and tools for enhanced decision support services.
- Evaluate forecast skill from the first year of experimental Week-3-4 temperature and precipitation outlooks and continue development of products; transition of Week-3-4 prediction tool based on Climate Test Bed project outcomes to operations.
- Support scientific advancements in understanding of tropical convection, the coupled ocean-atmosphere-land-ice system, and persistent model biases (e.g., DYNAMO, AMOC, and Pacific Ocean Biases).
- As an element of its suite of observation systems and partnerships, develop the plan for the Tropical Pacific Observing System 2020 projects which will support improved ENSO predictions as well as weather forecasts.
- Increase engagement with public and private partners to understand their vulnerability to extremes of weather and climate to help develop information needs and options for adaptation and mitigation.
- Expand the Climate Resilience Toolkit to offer map layers showing climate-related stressors, people and assets impacted, and climate projections and to facilitate knowledge sharing between climate experts and stakeholders in businesses and communities.

Earth System Research Laboratory (ESRL)

The Earth System Research Laboratory (ESRL) continues to make unparalleled contributions to the scientific understanding of climate change through its global atmospheric monitoring program, field missions to study atmospheric processes, laboratory studies, modeling work.

ESRL's 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.

The ESRL Global Monitoring Division (GMD) conducts sustained observations and research related to global distributions, trends, sources and sinks of atmospheric constituents such as greenhouse and other trace gases, aerosols, ozone, a that are capable of forcing change in Earth's climate. This research and long-term observations are used worldwide to advance climate projections and provide scientific, policy-relevant, decision-support information to enhance society's ability to plan and respond to change.

Physical Sciences Division (PSD) strives to interpret the causes of observed climate variation, and advance the understanding, parameterization, and measurement of climate-relevant physical processes. This knowledge is used to improve climate models and forecasts and develop new climate products that better serve the needs of the public and decision-makers.

All ESRL Divisions place a high priority on communicating the results of their research in decision-support information products to underpin national and international decision-making. Their contributions include leadership and extensive participation in state-of-understanding national and international assessments on climate.

FY 16 Plans:

- Carry out the Shale Oil and Natural Gas Nexus (SONGNEX) investigation using NOAA's "flying chemical laboratory" aboard the NOAA P-3 aircraft
- Execute a complementary airborne study of Fugitive Emissions concentrating on methane and other GHGs aboard the NOAA DHC6 aircraft.
- Analyze data from the SENEX and SEAC4RS field missions to understand climate effects of emissions, atmospheric chemistry, and transport in the southeastern U.S.
- Develop new prototype systems for regional drought diagnosis and prediction.
- Develop large ensemble, multi-model, high resolution global modeling ability to resolve high impact extreme events: heat waves, droughts, heavy precipitation.
- Develop climate and weather guidance to reduce and manage drought and floods impacts on watershed restoration.
- Provide an integrated database for the International Arctic System for Observing the Atmosphere (IASOA). IASOA is a consortium of 10 sentinel Arctic Observatories that collect a wide range of detailed measurements relevant to weather and climate. This activity will support the Polar Prediction Project.
- Lead development of International Arctic science focus groups integrating information on the environmental state of clouds, radiation, surface-atmosphere exchanges, trace gases, black carbon and regional predictions in the Arctic region.
- Continue development of Arctic atmospheric observatories to obtain high-latitude climate data.
- Engage in diagnostic studies to enhance understanding of the two-way linkages between the Arctic region and the lower latitudes to improve prediction
- Continue long-term observations of atmospheric composition, providing annual updates of CarbonTracker, the NOAA Annual Greenhouse Gas Index (a national climate indicator), methane climatologies, CO_2 trends (daily updates; a national climate indicator), the Ozone-Depleting Gas Index, GlobalView, and other long-term atmospheric composition data sets and products.

Geophysical Fluid Dynamics Laboratory (GFDL)

Over the last half century in general, and the last few years in particular, GFDL has demonstrated world leadership in pushing the boundaries of climate prediction and projections of climate change. 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 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 was used again in AR5. Nearly 200 terabytes of model output was submitted to the 5th Coupled Model Inter-comparison Project (CMIP5) for use in AR5. The four modeling streams are:

1. Decadal prediction experiments to better understand physical processes.
2. Earth System Models (ESMs), emphasizing biogeochemical carbon-climate feedbacks through the use of a closed-carbon cycle.
3. Coupled climate models (CM3) with more realistic, self-consistent but complex atmospheric physics and chemistry than in CM2.1.
4. High-resolution atmospheric models at 50km and 25km resolution forced by future ocean states.

GFDL scientists continue to play an active role in AR5, and in some instances lead, in: model inter-comparison and model simulation analysis activities; submission of model data, quality control and archiving; analyses of the data outputs and inferences about the climate system. These activities will lead to a number of peer-reviewed publications based on the CMIP5 database of model output. 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 and science results were also used in the recently released USGCRP National Climate Assessment. Significant progress in model development is expected in FY15 as the four modeling streams outlined above are unified into a new coupled model called CM4. New very high-resolution climate and Earth System models are being developed and applied to address scientific questions regarding the impact of atmospheric composition and ocean eddies on the climate system as well as regional-to-local impacts of climate variability and change on marine ecosystems.

Great Lakes Environmental Research Laboratory (GLERL)

The Great Lakes Environmental Research Laboratory (GLERL) conducts climate research and modeling focused on the region of the Laurentian Great Lakes, which is shared by the USA and Canada. Investigation of impacts of climate change on hydrologic resources in the Great Lakes began during the late 1980s, and has been considerably overhauled in recent years. Hydrologic models with one-way driving of the surface by the atmosphere have been replaced by regional climate models with two-way coupling of the atmosphere to both land and water surfaces. The

older generation of this type of model, the Coupled Hydrosphere-Atmosphere Research Model (CHARM) is being replaced by a newer version based on the Weather Research and Forecasting (WRF) model.

Of particular interest is the influence of climate and climate change on water quantity in the Great Lakes basin, and atmospheric and climatic research at GLERL are coordinated with hydrologic study, as well as research on the dynamics of motion and thermodynamics of the lakes and their ice. In addition, GLERL has expertise in the dynamics of nutrient loading in rivers, and on the interaction among these nutrients, water temperature and dynamics, and the biota of the lower and upper food web, leading to end-to-end capability in the physical, chemical, and biological aspects of this regional Earth system.

National Severe Storms Laboratory (NSSL)

NSSL scientists have collaborated with the NOAA NWS Storm Prediction Center to determine the observed climatology of severe thunderstorms in the U.S. and to explore different strategies for producing reliable seasonal predictions of severe weather. They have also worked with the international community to develop climatologies for other parts of the globe. In addition, they have examined data from different climate-projection studies, together with known relationships between environmental parameters and severe-weather occurrence, to hypothesize how severe-weather occurrence and intensity might change in different climate scenarios.

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. Key observational components include:

The Global Tropical Moored Buoy Array (GTMBA) was developed by PMEL in partnership with NOAA's Climate Program Office and multiple international partners. PMEL 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 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 under the direction of NOAA's Climate Program Office and in conjunction with U.S. Argo partners Scripps Institute of Oceanography, Woods Hole Oceanographic Institution, the University of Washington, and AOML. PMEL scientists deploy floats, support the addition of new measurement and increased depth capabilities of Argo floats, conduct research on improving quality control of the Argo data. PMEL and CPO are co-managing the development of Deep Argo floats, extending the depth range of Argo floats from 2,000 meters to 6,000 meters.

PMEL scientists support the OceanSITES program of global moored ocean reference stations for climate, maintaining two moored platforms in the North Pacific, at the Kuroshio Extension Observatory (32.3^{o}N 144.5^{o}E) in the NW Pacific Ocean and at Ocean Station Papa (50°N 145°W) in the NE Pacific Ocean.

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.

U.S Department of Agriculture

National Institute of Food and Agriculture

National Institute of Food and Agriculture (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.

Climate impacts on human, environmental and plant and animal health is also well 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 is currently focused research areas are, 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, biofuel feedstock

production and economic consequences of adaptation and mitigation strategies. Emerging areas of research include the impact of climate on environmental markets, food safety, and soil health.

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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.

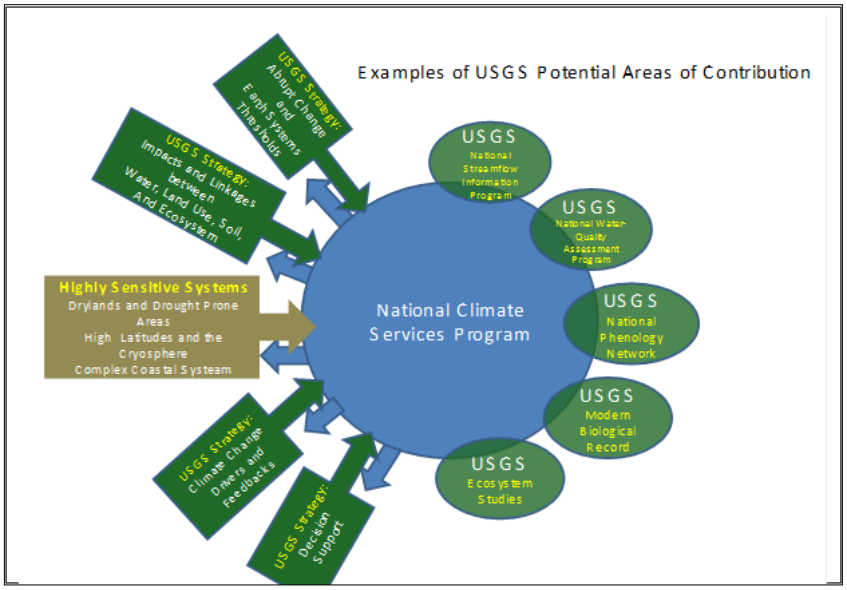


Figure 5: Examples of USGS Potential Areas of Contribution

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 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 National Aeronautics and Space Act of 1958 calls for NASA to conduct activities in space to expand human knowledge of the Earth and of phenomena in the atmosphere and space. The 2010 National Space Policy further states that the National Aeronautics and Space Administration (NASA) "shall conduct a program to enhance U.S. global climate change research and sustained monitoring capabilities, advance research into and scientific knowledge of the Earth by accelerating the development of new Earth observing satellites, and develop and test capabilities for use by other civil departments and agencies for operational purposes." 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.

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.

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 has 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 mass change and other characteristics; 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, sea level rise, and study of the earth as a system.

NASA has 11 on-orbit satellite missions related to climate services, as defined by this Federal Plan: Aqua, Aquarius/Satélite de Aplicaciones Científicas (SAC)-D, Aura, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), CloudSat, Global Precipitation Measurement (GPM), the International Space Station (ISS) - Cloud-Aerosol Transport System (CATS) and RapidScat payloads, Ocean Surface Topography Mission (OSTM), Orbiting Carbon Observatory-2 (OCO-2), Quick Scatterometer (QuikSCAT), Soil Moisture Active Passive (SMAP) mission, and Suomi-National Polar-orbiting Partnership (Suomi NPP). The Tropical Rainfall Measuring Mission (TRMM), formerly on the list, was decommissioned April 15, 2015. OCO-2 was launched on July 2, 2014. ISS-RapidScat was launched on September 20, 2014, and installed on the ISS a few days later. CATS was launched on January 10, 2015, and also installed on the ISS. On January 31, 2015, SMAP was launched successfully and recently completed on-orbit checkout, transitioning to nominal mission operations on May 11, 2015. SMAP is the first of the Tier 1 missions of the Decadal Survey. Table 1 lists the climate services themes supported by these missions.

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

Satellite	**Launch Date**	**Climate Services Theme**
QuikSCAT	Jun 1999	Climate Variability and Change
Aqua	May 2002	Atmospheric Composition; Carbon Cycle; 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
Aquarius	Jun 2011	Climate Variability and Change; Water Cycle
OSTM	Jun 2008	Climate Variability and Change; Water Cycle
Suomi NPP	Oct 2011	Atmospheric Composition; Carbon Cycle; Climate Variability and Change; Water Cycle
GPM	Feb 2014	Climate Variability and Change; Water Cycle
OCO-2	Jul 2014	Climate Variability and Change, Atmospheric Composition, Carbon Cycle

ISS RapidScat	Sept 2014	Climate Variability and Change
ISS CATS	Jan 2015	Atmospheric Composition, Water Cycle
SMAP	Jan 2015	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 nearly simultaneously globally. To address this challenge, NASA has engineered constellations of satellites flying in close formation. For example, NASA's Aura, CALIPSO, CloudSat, Aqua, and OCO-2 satellites, together with the Japanese Global Change Observation Mission 1–Water "Shizuku" (GCOM-W1), are called the "A-Train" constellation and produce an unprecedented quantity of data for atmospheric composition, dynamics and the water cycle. 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 4 satellite missions in development (Table 2) related to climate services, as defined by this Federal Plan, for launch from 2016 to 2020. Cyclone Global Navigation Satellite System (CYGNSS) is the first in the Earth Venture-class series of rapidly developed, cost-constrained small space missions, and is referred to as EVM-1 (Earth Venture Mission-1). Tropospheric Emissions: Monitoring of Pollution (TEMPO) is the first in the Earth Venture-class series of instrument missions of opportunity that will fly as hosted payloads on commercial or government satellites. Surface Water and Ocean Topography (SWOT) is a Tier 2 Decadal Survey mission that was accelerated by the Climate Initiative to provide insight into the movement and distribution of Earth surface waters including both freshwater and oceans. Pre Aerosol, Clouds, and ocean Ecosystem (PACE) mission has been directed to Goddard and is currently in pre-formulation.

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

Satellite	**Planned Launch**	**Climate Services Theme**
CYGNSS	2016	Water Cycle
TEMPO	nlt2023	Atmospheric Composition; Climate Variability and Change
SWOT	2020	Climate Variability and Change; Water Cycle
PACE	2022/2023	Carbon Cycle

NASA continues with the pre-formulation studies of Decadal Survey and other mission concepts such as Climate Absolute Radiance and Refractivity Observatory (CLARREO), Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS), Aerosol-Cloud-Ecosystem (ACE), GEOstationary Coastal and Air Pollution Events (GEO-CAPE), Hyperspectral Infrared Imager (HyspIRI), *Lidar Surface Topography* (LIST), Precision and All-Weather Temperature and Humidity (PATH), Gravity Recovery and Climate Experiment II (GRACE-II), Snow and Cold Land Processes (SCLP), *Global Atmospheric Composition Mission* (GACM) and Three-

Dimensional Tropospheric Winds from Space-based Lidar (3-D Winds). Additionally, the Earth Science Technology Office (ESTO) makes significant investments in technology development activities directly addressing the priorities outlined in the Decadal Survey including the tiered missions as wells as Earth Venture through development of observation systems and information systems technologies.

The following activities will be undertaken or accomplished in FY 2016.

- CYGNSS will complete environmental test and prepare for launch in earl FY17.
- TEMPO will continue its development, including instrument level integration and test.
- SWOT will complete its Key Decisions Point – C (KDP-C) review and enter development.
- PACE will complete its Mission Concept Review (MCR) and Key Decision Point – A (KDP-A) review and enter formulation.
- QuikSCAT will be decommissioned, and its cross-calibration role for other scatterometers transitioned to the RapidScat instrument on the International Space Station, which has also resumed production of ocean wind vectors data for operational use.

NASA Science Research

NASA's Earth Science Research Program addresses complex, interdisciplinary Earth science problems in pursuit of a comprehensive understanding of the Earth system. The Research Program pioneers the use of both space-borne and aircraft measurements through its implementation of several elements: multi-disciplinary research and analysis, interdisciplinary research, data product generation, calibration and validation, airborne science, modeling and data assimilation, and enabling capabilities. Research and analysis (R&A) emphasizes the development of new scientific knowledge, including the analysis of data from NASA satellite missions and the development and application of complex models that assimilate these science data products and/or use them for improving predictive capabilities.

The following research activities will be undertaken or accomplished in FY 2016:

- Continue expanding the supercomputing capacity to more than 4 quadrillion floating point operations per second (petaflops) for weather and climate modeling using the combination of CPUs and multi-core accelerator technologies such as Intel Phi and NVIDIA GPU processors. The storage system capacity will continue to grow to more than 40 petabytes to accommodate the data generated by high-resolution model simulations including the nature run for Observation System Simulation Experiment (OSSE), reanalysis for climate data record, and high-resolution climate projection downscalings.
- Increase the number of science data products delivered to Earth Observing System Data and Information System (EOSDIS).
- Continue operation of ground networks such as TOLNet, AERONET, and MPLNET for measuring time evolution of atmospheric trace constituents, including gases and aerosols.
- The Earth Venture Suborbital-2 (EVS-2) proposals have been reviewed and selections were made in November 2014. Of particular relevance because of their emphasis on atmospheric composition and its effect on meteorology include ObseRvations of Aerosols Above Clouds and Their IntEractionS (ORACLE), North Atlantic Aerosols and Marine Ecosystems Study (NAAMES), and Atmospheric Carbon and Transport – America (ACT-America). These new projects are in the process of getting started. The Earth Venture Suborbital-1 (EVS-1)

missions are finishing up and include the following research (observation investigations were mostly completed in FY14, some will continue into FY15, analysis of scientific data will continue in FY15):

- The Hurricane and Severe Storm Sentinel (HS3) EVS-1 investigation used two Global Hawk unmanned aircraft systems (UAS) and the NASA WB-57 manned aircraft (2014 only) around and above hurricanes. One Global Hawk payload was optimized for direct observations of the hurricane inner-core region. The other payload included sensors that measured important parameters in the region surrounding the storm to help improve our understanding of tropical cyclone genesis and intensification. HS3 results are being used to improve our ability to predict storm path and intensity. Over three years of measurements (2012-2014), HS3 performed 19 overflights of 9 named Atlantic tropical cyclones and also sampled several non-developing tropical waves and the Saharan Air Layer. Analysis of the data is ongoing in FY15 and will be completed in FY16.
- The Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) EVS-1 investigation has finished its airborne flights using an ultra-high frequency synthetic aperture radar to measure high spatial resolution soil moisture to provide insight into the vegetation activity and the uptake of carbon dioxide. In FY16, the project will finish its work by analyzing collected data and model simulations to achieve its goal of reducing the uncertainty of global NEE (Net Ecosystem Exchange) estimates.
- The Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) EVS-1 investigation uses airborne and ground-based measurements of trace gases and aerosols, correlated with satellite remote sensing measurements, to improve our ability to characterize and predict air quality. The project will continue efforts to characterize a variety of urban environments based on its observations in the Washington-Baltimore, Houston, Sacramento-Central Valley, and the Denver area completed in the 2011-2014 time period.

- The second Earth Venture Instrument (EVI-2) selections were made in late FY14. The release of the third Earth Venture Instrument solicitation (EVI-3) was made in FY15 with selections expected in FY16. The selected mission from EVI-1 (TEMPO, to be hosted on a commercial geostationary satellite) received agency confirmation in FY15 and is now in the implementation phase.
- The Earth Venture Mission-2 (EVM-2) CYGNSS project has made significant progress. The science product algorithms are proceeding well and testing has started using the selected nature model. The satellite observatories and constellation has completed the detailed design and is beginning fabrication and test of flight hardware.

Department of Energy

Office of Science/ Biological and Environmental Research (BER) / Climate and Environmental Sciences Division (CESD)

CESD supports an integrated portfolio of basic research ranging from molecular to field scale studies with emphasis on the use of advanced computer models and multidisciplinary experimentation. As discussed, in http://science.energy.gov/ber/research/cesd/, CESD supports

three groups of research activities, i.e., atmospheric sciences, environmental biogeochemistry, and earth system modeling. These three groups exploit two DOE scientific user facilities that focus on atmospheric and environmental observations to advance predictive understanding.

The atmospheric research activities are comprised of the Atmospheric System Research (ASR) Program and the Atmospheric Radiation Measurement (ARM) Climate Research Facility. Together, the ASR Program and ARM facility strive to understand the physics and dynamics governing cloud, aerosol, and precipitation interactions as well as to advance an understanding of cloud evolution and radiative energy balance. As a world class observing capability, the ARM facility is comprised of a suite of radars, lidars, and in-situ observations of clouds, aerosols, and radiative transfer, supplemented by manned and unmanned aircraft. Permanent sites are located in the Southern Great Plains (Oklahoma), Arctic (Barrow), and eastern Atlantic (Azore Islands); there are three mobile facilities deployed for durations of 6 months to several years to conduct targeted research. Beginning in FY 2016, the ARM facility will begin to incorporate Large Eddy Simulations as an operational component of the SGP site.

The environmental investments within CESD are composed of the Terrestrial Ecosystem Program, Subsurface Biogeochemistry Program, and the Environmental Molecular Sciences Laboratory (EMSL) User Facility. These activities are designed to advance the ecological and hydrological sciences, in order to improve a predictive understand of the process interactions appropriate for land and climate and earth system modeling. Major field activities include decadal scale experiments associated with studies of Arctic permafrost, boreal systems, tropical ecology, and river basins, each with a modeling component that links to earth system predictability research.

CESD modeling investments include a major emphasis on Earth System Model development, model analysis, and integrated assessment. Driven in large part by DOE's goal to advance computational hardware and software capabilities to support increasingly complex scientific challenges, DOE has emphasized the prediction of extreme events, scale aware physics, nonhydrostatic-hydrostatic dynamics, and impact assessments. The Advanced Climate Model for Energy (ACME) is a new modeling platform, initiated in FY 2014, with links to the Community Earth System Model (CESM). A human component was added to the ACME framework that incorporates the Global Change Assessment Model (GCAM).

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 collaborative groups, as well as funding for the National Center for Atmospheric Research (NCAR). NSF invests in the Community Earth System Model (CESM), a fully-coupled global climate model that provides state-of-the-art simulations of the Earth's past, present, and future climate states. NSF also funds the supporting infrastructure for climate studies by making computing resources required to perform data-intensive simulations available for community use.

As a basic science funding agency, NSF does not directly provide climate services to federal, state, and local agencies. But through its funding of basic science research, NSF contributes to the fundamental understanding of the climate system which is required for the provision of climate services.

Figure 6: The NCAR-Wyoming Supercomputing Center provides advanced computing services to scientists studying a broad range of disciplines, including weather, climate, oceanography, air pollution, space weather, computational science, energy production, and carbon sequestration. It also houses a landmark data storage and archival facility that will hold, among other scientific data, unique historical climate records. Courtesy: University Corporation for Atmospheric Research

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 dispersion (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

OPERATIONAL PROGRAMS INCLUDING PRODUCTS AND SERVICES

Federal Emergency Management Agency

The Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) authorizes the President to provide financial and other support to state, local, tribal, territorial, and insular area governments to support response, recovery, and mitigation efforts following a major emergency or disaster. Under the Stafford Act, when an incident occurs that overwhelms the resources of a state or tribe, and the governor or tribal leader requests federal disaster assistance, the President may issue a Stafford Act declaration of either an "emergency" or "major disaster". This declaration triggers the Federal Emergency Management Agency's (FEMA's) authorities to provide and coordinate response and recovery assistance. The Federal government may also mobilize and deploy assets in anticipation of a formal request from the state for Federal support.

Per the Post-Katrina Emergency Management Reform Act (PKEMRA), FEMA leads and supports the Nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation. PKEMRA also requires that each federal agency with responsibilities under the National Response Framework (NRF) develop operational plans to ensure a coordinated federal response. The NRF established 14 Emergency Support Functions (ESFs) that are comprised of departments and agencies with particular authorities, resources, capabilities, and expertise to coordinate sector-specific disaster response actions.

In 2011, the President directed the development of a new National Preparedness System (NPS) that includes a National Planning Framework for each of five mission areas - prevention, protection, mitigation, response, and recovery. These frameworks identify how the whole community will build and deliver the core capabilities required to address the threats that pose the greatest risks to our Nation. The President also directed the development of a Federal Interagency Operational Plan (FIOP) to support each of these frameworks and to describe how the Federal government will execute its responsibilities in support of state, local, tribal, and territorial efforts.

The FIOP for Response, for example, is an all-hazards plan based on a "maximum of maximum" scenario that includes multiple catastrophic incidents and cascading impacts, including a major earthquake, a major land-falling hurricane, and a nuclear incident. Such a scenario would occur over a large geographic area, affect millions of people, and require response and recovery capabilities from across the whole community to include government at all levels, public and private sector resources, non-governmental organizations, and individual citizens. The concepts and tasks outlined in the FIOP for Response are scalable, flexible, and adaptable and can be used regardless of cause, size, location, or complexity of incidents.

The mission of the 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.

Figure 1: FEMA's interagency collaboration and support is key to disaster impact assessments and plans.

The Response Directorate within FEMA administers the National Hurricane Program (NHP), which provides tools, training and technical assistance to support local, state, and federal hurricane planning and response. The NHP conducts hurricane evacuation studies, provides hurricane decision support tools, and delivers hurricane planning and decision making training for government emergency managers. Under an Interagency Agreement between FEMA and 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 to provide planning and operational products to support storm surge risk analysis. The operational products are used to support state and local evacuation decisions and are used at all levels of government to prepare for the potential impacts and response. The planning products are used as the basis for the hazard analysis conducted Hurricane Evacuation Studies (HESs) and to assess the potential storm surge risk for a hurricane threat prior to the availability of the operational products.

As part of the NHP, FEMA also develops, operates, maintains and distributes the HURREVAC decision-support software tool to approximately 20,000 local and state government coastal emergency managers annually. HURREVAC combines real-time NHC forecast data with evacuation clearance times from the HESs to guide emergency managers as to when decisions on hurricane evacuations would need to be made to ensure evacuation is completed before the arrival of hazardous conditions. The software is also widely used as a situational awareness and briefing tool and as a common operating platform to view official NHC hurricane forecast and risk information.

The NHP supports training and technical assistance for emergency managers through coordination with between FEMA, the NHC, and other program partners. The NHC provides training materials and instructors for NHP hurricane planning and decision making courses taught at the NHC and at conferences and State Emergency Operations Centers. The NHC also directly supports the FEMA Hurricane Liaison Team (HLT), which ensures the rapid exchange of forecast and risk information between the NHC and the emergency management community. FEMA has also deployed a permanent liaison to the National Weather Service's Storm Prediction Center (NWS/SPC) to ensure similar information flow between SPC and the emergency management community regarding severe thunderstorm risks, primarily with respect to tornadoes and damaging winds.

The Federal Insurance and Mitigation Administration (FIMA) which manage the National Flood Insurance Program (NFIP) is looking to be part of IWRSS (Integrated Water Resources Science and Services) (P 2-139 Emergency Response and Homeland Security Services).

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. *(see related COASTAL Act narrative on page 2-6)* 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.

U.S. Coast Guard

The U.S. Coast Guard (USCG) directly supports all Department of Homeland Security (DHS) missions. It provides DHS the broad authorities, capabilities, and partnerships necessary to accomplish its tasks in the maritime domain.

Coast Guard has three broad roles: Maritime Safety, Maritime Security, and Maritime Stewardship. Each USCG role is composed of several statutory missions. Each of the eleven statutory missions is listed below under the appropriate role.

- Maritime Safety Missions
  - Marine Safety
  - Search and Rescue
- Maritime Security Missions
  - Drug Interdiction
  - Migrant Interdiction
  - Defense Readiness
  - Ports, Waterways, and Coastal Security
- Maritime Stewardship Missions

- Living Marine Resources
- Marine Environmental Protection
- Other Law Enforcement (Fisheries)
- Aids to Navigation
- Ice Operations

Most USCG missions support more than one role. For example, the Aids to Navigation mission primarily supports the Maritime Stewardship role by preventing pollution from vessel groundings and collisions, while facilitating the movement of people and goods. But this mission also supports our Maritime Safety Role by preventing accidents, injuries, and deaths. These interwoven roles and complementary missions call for Coast Guard personnel and resources that are similarly multi-mission capable. This characteristic of USCG people and platforms—their ability to perform multiple missions—brings greater effectiveness, insight, and agility to bear in any situation. It is a fundamental source of the Coast Guard's strength. Support for meteorological operations and supporting research is detailed in other sections of this plan.

Interagency Modeling and Atmospheric Assessment Center

The IMAAC provides a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position during actual or potential incidents involving hazardous atmospheric releases. Through plume modeling analysis, the IMAAC provides emergency responders, as well as public health and emergency managers and planners with predictions of hazards associated with atmospheric releases to aid in the decision making process to protect the public and the environment.

The IMAAC is managed by the Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) and supported by other federal departments and agencies including the Department of Defense (DoD), Department of Energy (DOE), Department of Health and Human Services (HHS), Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and Nuclear Regulatory Commission (NRC). The IMAAC Technical Operations Hub is operated by the Defense Threat Reduction Agency (DTRA).

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 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 as well as variety of other available numerical weather prediction models (NWP) for the plume products. During IMAAC activations, the IMAAC Technical

Operations Hub will consult with NOAA to determine the preferred higher-resolution forecast model for the event and will utilize that model if possible.

The IMAAC has been used in response 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 Incident Management System and Emergency Support Functions

NOAA's National Weather Service (NWS) has derived responsibility to support the emergency operations of local, state, tribal, territorial, and insular area governments through the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988. Further the Department of Homeland Security's (DHS) National Response Framework (NRF) mandated by Presidential Policy Direction 8 provides the context for how the Nation responds to disasters and emergencies through the establishment of a National Incident Management System and Emergency Support Functions to align key roles and responsibilities. This Framework describes specific authorities and best practices for managing incidents that range from the serious local to large-scale terrorist attacks or catastrophic natural disasters.

NWS Impact-based Decision Support Services (IDSS) are provided for National Special Security Events as designated by the Secretary of Homeland Security, to Department of Homeland Security (DHS) coordinated Special Event Assessment Rating events, and in response to Incidents of National Significance (e.g., Hurricane Sandy). NWS can deploy Incident Meteorologists (IMETs) and Emergency Response Specialists 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 has an embedded meteorologist at FEMA Headquarters to provide real-time decision support to FEMA and other national government decision makers. In addition, the liaison (along with additional NWS meteorologists when necessary) will support activations at the National Response Coordination Center as a result of any major disaster or emergency. Similarly, NOAA has a liaison deployed to the DHS National Operations Center.

Post Storm Data Acquisition

NOAA NWS supports the OFCM-sponsored Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (WG/DIAP) and its 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. NWS trains volunteer SKYWARN® weather spotters to help assess weather and flood incidents. NWS conducts field surveys of damage utilizing the Damage Assessment Toolkit (https://apps.dat.noaa.gov/StormDamage/DamageViewer/)and leverages NOAA aircraft and the USAF Auxiliary's Civil Air Patrol for overflight reconnaissance. High resolution satellite imagery can also be acquired for major incidents.

Data collected by the NWS contributes to Governors' Disaster Declaration Requests, Preliminary Damage Assessment Reports and to FEMA's evaluations. Data acquired by NOAA NWS is

shared through the WG/DIAP and officially published in NOAA's National Centers for Environmental Information's (NCEI) *Storm Data* (http://www.ncdc.noaa.gov/IPS/sd/sd.html).

FEMA Integrated Public Alert and Warning System (IPAWS) and Wireless Emergency Alerts.

The NWS pushes watches, warnings, advisories, and special statements in Common Alerting Protocol (CAP) format to the FEMA IPAWS Alert Aggregator. Warnings which pose an "imminent threat" to the general public pass through IPAWS to commercial wireless carriers and are broadcast as a 90 character WEA message on WEA-capable devices. 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). Almost all wireless carriers provide the WEA service and the majority of devices on the market are now WEA- capable.

The NWS is actively collaborating with commercial wireless industry as well as Federal, emergency management, and academic partners in multiple Federal Communications Commission (FCC)-tasked working groups which have been tasked to identify possible future improvements to WEA.

The NWS and FEMA have made NWS CAP messages available over FEMA IPAWS and multiple NWS dissemination systems for repackaging and redistribution by alert distribution partners. The NWS also continues working with FEMA, the FCC, broadcast industry, and related partners on solutions which would provide compatibility between NWS-produced CAP and Emergency Alert System (EAS) signals broadcast by NOAA Weather Radio (NWR), so that NWS-CAP could be used to activate EAS.

NOAA Weather Radio (NWR).

NWR is used as a reliable and redunant means of communicating weather-related warnings directly to the public. NWR is a nationwide network of radio stations broadcasting continuous weather information directly from the nearest National Weather Service office. NWR broadcasts official NWS warnings, watches, forecasts and other hazard information 24 hours a day, 7 days a week. Working with the FCC EAS, NWR is an "All Hazards" radio network, making it a single source for comprehensive weather and emergency information. In conjunction with Federal, State, and Local Emergency Managers and other public officials, NWR also broadcasts warning and post-event information for all types of hazards – including natural (such as earthquakes or avalanches), environmental (such as chemical releases or oil spills), and public safety (such as AMBER alerts or 911 Telephone outages).

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/National Ocean Service

Center for Operational Oceanographic Products and Services (CO-OPS) Resilience Program

In 2014, NOAA CO-OPS rebranded the CO-OPS COASTAL Program to the CO-OPS Resilience Program. This Program continues to focus on non-navigational applications of CO-OPS observing systems, data, and products for ecosystem restoration and management. The Resilience Program 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 for elevated water levels in the Mississippi River that occurred in 2011. These bulletins provide near real-time, continuously updating oceanographic and meteorological data measured at affected water level stations. 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.

In FY15, CO-OPS completed the following improvements to this product:

- Updated the base map used in the QuickLook product by taking advantage of NOAA's ESRI Enterprise User Agreement.
- Better integrated the product with the Tides and Currents website by activating the header, making it easier to navigate to other CO-OPS web products.
- Improved the products ability to scale based on browser size, which has greatly improved use on mobile devices.

The CO-OPS Resilience Program 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. For more information see http://tidesandcurrents.noaa.gov/coastal.html.

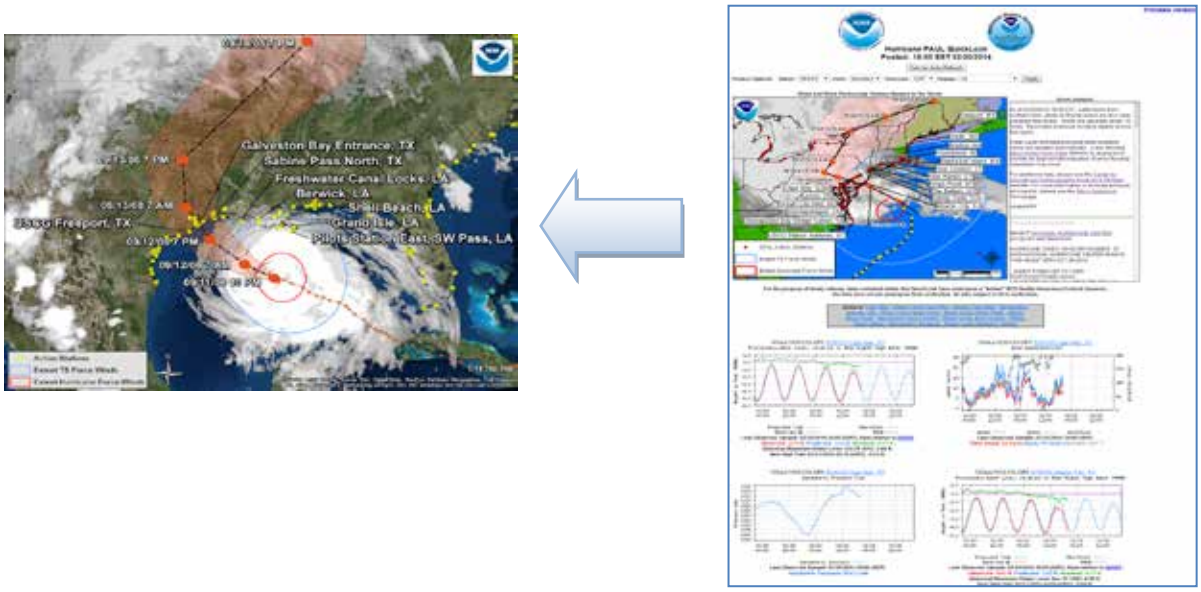


Figure 2: Updated the base map used in the Storm QuickLook product added in FY15

NOAA/Office of Marine and Aviation Operations

Among the NOAA/OMAO airborne observing systems fleet, the King Air (N68RF) and the Twin Otters (4 aircraft) can perform damage assessment flights following natural disasters. They provide georeferenced, 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 as part of the FEMA National Response Framework.

United States Air Force

Air Force (AF) weather personnel enable DoD decision-makers to anticipate and exploit the weather for air, ground, space, cyberspace, and intelligence operations. As this applies to 'Emergency Response and Homeland Security Services,' the AF provides meteorological 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. Strong interagency partnerships provide access to data sources, insight into emerging science and technology, and help all parties leverage limited budgets by reducing redundancy and pooling capabilities. Air Force weather personnel and capabilities may also be leveraged for Defense Support of Civil Authorities operations. Different AF organizations support various aspects of the Nation's homeland security efforts:

- The AF, through the 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). The AF's 2nd Weather Group 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. The 2nd Weather

Group also produces space weather products used to support both the daily and emergency response and homeland security operation of USNORTHCOM and NORAD.

- The AF produces both CONUS and worldwide geospatial representations of current and forecast weather used to support the National Geospatial-Intelligence Agency (NGA) in their homeland security mission.
- The AF 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 AF's CONUS and overseas Operational Weather Squadrons, who provide regional reachback support aligned with the Geographic Combatant Command areas of responsibility, may support emergency planning and response operations for US interests at home or abroad. The Joint Typhoon Warning Center (JTWC), operated jointly with the 17th Operational Weather Squadron (17 OWS) and the Navy in Hawaii, routinely works with its sister U.S. and international tropical cyclone forecast centers to issue forecasts and warnings to protect U.S. DoD assets across the Pacific and Indian Ocean basins.
- The Air Force Reserve Command's 53rd Weather Reconnaissance Squadron "Hurricane Hunters" collect meteorological data in and around tropical cyclones, providing timely and accurate data to the National Hurricane Center to aid in their analysis, prediction and warning products to help mitigate and protect lives and property impacted by these tropical systems.

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. Military oceanographic survey vessels designated as T-AGS are continuously forward deployed and conduct hydrographic, oceanographic and acoustic surveys in all the oceans of the world. These ships have modern full ocean depth multi-beam and single-beam sonar systems for accurately measuring bottom depths and features, towed side-scan sonar systems for acoustic imaging of bottom features and navigation hazards, ocean current profilers, sub-bottom profilers for measuring stratification of seabed sediments, and over-the-side devices that collect physical ocean parameters such as temperature and salinity with depth. These ships are capable of hosting a number of roll-on/roll-off systems, including systems for collection of seismic data and unmanned underwater vehicles. The ships are also equipped with C-band communications to send data directly back to the Naval Oceanographic Office for immediate processing. Three of the ships are complemented with hydrographic survey vessels — smaller craft for shallow water hydrographic collection. We have been operating unmanned underwater vehicles (UUVs) for well over a decade. Their inventory consists of propelled vehicles, such as various models of the Remote Environmental Monitoring Units (REMUS) UUVs for collection of sonar, sub-bottom and optical data in addition to buoyancy controlled, high endurance UUVs, such as the Slocum glider and wave-powered Sensor Hosting Autonomous Remote Craft (SHARC) vehicles, which collect and transmit ocean and atmospheric data in real time for satellite transfer back to our operational production centers. Navy uses UUVs for direct support to operation missions. As part of our hydrographic capability, they also employ unique jet-ski variants called Expeditionary Survey Vehicles or ESVs. Outfitted with single-beam and side-scan sonar, in addition to accurate Global Positioning System navigation, ESVs can be rapidly deployed and conduct hydrographic survey into the surf

zone, to places where traditional systems can't go. This data is extremely useful for supporting expeditionary warfare and enabling missions like humanitarian assistance and disaster response. 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.

Partnerships and Stability Operations

Figure 3: Unmanned Autonomous Vehicle used for hydrographic surveying from a T-AGS vessel

Partnerships provide access to data sources, insight into emerging science and technology, and help all parties leverage limited budgets by reducing redundancy and pooling capabilities. Naval operational oceanography has a long history of executing cooperative military hydrographic and oceanographic surveys, as well as data, product and subject matter exchanges with international partners. Their ability to provide emerging partners with improved capabilities in the areas of meteorology, oceanography and hydrography is unique and is highly regarded by combatant commanders and naval component commanders as an outstanding tool for strategic engagement. In turn, their partners provide access to information vital to forward-deployed naval operations.

Navy METOC also maintains strong interagency partnerships. The integration of modeling efforts among the Navy, National Oceanic and Atmospheric Administration (NOAA), and U.S. Air Force, NUOPC provides an unparalleled global modeling capability that can be adapted by individual agencies for specific applications. Another strong example is their partnership with NOAA and the U.S. Coast Guard in operating the U.S. National/Naval Ice Center, providing ice analysis and forecasts to support safety of navigation for public, commercial and DoD use in the Arctic, Antarctic, Great Lakes, and all other large bodies of water affected by ice.

U.S. Marine Corps

Chemical Biological Incident Response Force

The CBIRF METOC Analyst serves to provide essential meteorological and hazardous prediction information in support of CBIRF`s real world and training operations coupled with providing daily and weekly weather forecasts and climatological briefs to the corresponding staff to support planning operations and typical battalion operations. Other duties include: research and implement new weather forecasting techniques or tools as well as new plume modeling software or tools; responsible for coordinating and maintaining liaison with local, state, and federal agencies such as the Department of Homeland Security, Defense Threat Reduction Agency (DTRA), or Joint Task Force Civil Support (JTF-CS) in order to enable appropriate

sharing of information and a combined arms response to Chemical Biological Radiological Nuclear Explosive (CBRNE) incidents that may occur within CBIRF`s purview; and work with the Battalion Chemist to develop plume modeling products that are disseminated in response to training or real world CBRNE events.

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.

Department of Energy

Field Site and National Laboratory Meteorological Services

In support of its national security, scientific research, and environmental stewardship missions, DOE has established 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 response and homeland security services among other activities. With respect to these programs, field sites and national laboratories collect quality-assured meteorological data, develop site-specific climatology from these measurements, use these data for various applications, and provide local site weather forecasting.

Emergency response and homeland security services require characterization of atmospheric processes that determine fate and transport of hazardous material releases. Meteorology programs directly contribute to the protection of public health and safety, and the environment, by accurately measuring and characterizing relevant local atmospheric processes to establish real-time and forecasted consequences.

DOE sites benefit from well-managed meteorological program support to 24/7 operations (e.g., work-force safety under severe weather and emergencies) and national defense programs.

Field Site and National Laboratory Operationao Meteorological Support

Operational meteorology programs provide customized meteorological monitoring services and local site weather forecasts for national defense projects, and for nuclear safety and emergency response programs. Each operational program is primarily focused on supporting emergency response, and protecting the safety of workers, public and the environment.

Operational meteorology programs are established at eight national laboratories, three reservations, Pantex, and Waste Isolation Pilot Plant. Some of these programs incorporate 24/7 severe weather watches to reduce risk of potential adverse impacts on facilities, construction projects, property, and workers:

- Two sites have received a National Weather Service (NWS) Storm Ready certification and other sites are pursuing this certification;
- Lightning protection and safety initiatives are integral elements of facility and worker safety systems supported by operational meteorology programs at eight locations;
- State-of-the-art instrumentation, including vertical profilers, sound detection and ranging instruments, and sonic anemometry, are employed in site monitoring networks; and,
- Data from some sites are part of the NWS database through the Meteorological Assimilation Data Ingest System.

The DOE Meteorological Coordinating Council, established in 1994, provides a forum for continuity of meteorological activities at DOE sites. Information on this council can be located at www.orise.orau.gov/emi/dmcc.

Many DOE reservations and national laboratories are located in areas with heterogeneous surface characteristics (e.g., land-water interface, mountain-valley morphology, forests) and experience complex localized weather conditions and resultant airflow trajectories. At these locations,

diagnostic and prognostic characterization of local three-dimensional wind fields is required to determine trustworthy consequence assessments. Accordingly, multi-location comprehensive meteorological monitoring systems are essential at these facilities. Oak Ridge National Laboratory (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 while other sites have extensively studied site-specific atmospheric flow phenomena to calibrate ATD capabilities.

Finally, several DOE sites use NOAA's Weather Research Forecasting mesoscale model as a component of its emergency response prognosticative capability.

Nuclear Regulatory Commission

The Nuclear Regulatory Commission (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 effects of 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.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NOAA/Office of Oceanic and Atmospheric Research (OAR)

Atlantic Oceanographic and Meteorological Laboratory (AOML)

AOML conducts mission oriented scientific research that seeks to understand the physical, chemical, and biological characteristics and processes of the ocean and atmosphere, both separately and as a coupled system. While the focus of the laboratory is on improving understanding through research, AOML houses a large component of the global ocean observing system, including Argo profiling floats and surface drifters. AOML also has maintained the long-standing expendable bathythermograph (XBT) program, which has a long-standing collaboration with the National Weather Service and the United States Coast Guard to develop and support the AMVER program. The AMVER program (Automated Mutual-Assistance Vessel Rescue AMVER reports allow the U. S. Coast Guard to track a vessel's position. The AMVER program relies on ships to submit four types of reports: (1) Sail Plans; (2) Position Reports; (3) Arrival Reports and (4) Deviation Reports, when necessary. The U. S. Coast Guard updates their database with the position information from these reports, which allows them to identify vessels in the vicinity of a ship in distress. AOML mains the software and processes all reports.

Air Resources Laboratory (ARL)

NOAA's Air Resources Laboratory (ARL) develops and improves dispersion and air quality models and collects research-grade atmospheric measurements. Our programs support NOAA, broader US, and some international emergency response programs with an emphasis on

chemical, nuclear, smoke, dust, and volcanic ash events. Our key NOAA customer is the National Weather Service, and we interact extensively with the National Ocean Service Office of Response and Restoration. ARL also provides a broad selection of web based assessment tools. ARL's primary emergency response model platform is the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model and has been made operational at NOAA's National Centers for Environmental Prediction (NCEP). HYSPLIT also serves as the national dispersion forecasting capability in several other countries. 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 provides meteorological support for the Department of Energy at the Idaho National Laboratory (INL) in Idaho Falls and at the Nevada National Security Site (NNSS) north of Las Vegas. ARL meteorologists staff the DOE Emergency Operations Center during drills and emergencies, such as accidental toxic chemical releases and wildfires. ARL operates an additional mesonet in East Tennessee that collects ozone and basic meteorological information.

In FY16, ARL will:

- Continue to improve and adapt the HYSPLIT model to address threats imposed from radioactive material, volcanic ash, dust, and wildfire smoke, and other hazardous materials.
- Provide reach-back support to NWS and other organizations that use our models.
- Continue to maintain mesonets in Nevada, Idaho, and eastern Tennessee.
- Continue to support the Department of Energy at the INL and NNSS.

Great Lakes Environmental Research Laboratory (GLERL)

The Great Lakes Environmental Research Laboratory (GLERL) has developed and continues to upgrade the Great Lakes Coastal Forecasting System (GLCFS). This system produces forecasts of waves, currents, temperature, ice, and other properties of the five Great Lakes and their connecting channels that are used by commercial ship captains, recreational boaters, fishermen, beach managers, oil spill responders, and search and rescue personnel. The GLCFS is currently being upgraded from a system based on the Princeton Ocean Model (POM), to a system based on the Finite Volume Coastal Ocean Model (FVCOM), which allows the model to be executed with variable spatial resolution, among other capabilities. The FVCOM versions of the GLCFS will become operational in FY2014, starting with Lake Erie.

The NOAA Great Lakes Regional Collaboration Team has also recently completed a technical memorandum that describes the particular roles and responsibilities for different NOAA offices and personnel in the Great Lakes in the event of a natural or human-caused emergency such as a severe winter storm, large wildfire, or oil spill. The team will be assisting other NOAA regions in FY2014 to adapt this approach for use in their areas, with consideration of the particular emergencies that might be anticipated in other regions such as hurricanes or earthquakes.

National Severe Storms Laboratory (NSSL)

NSSL collaborates with the NWS on research and development activities to advance our knowledge and understanding of severe convective storms and to provide new and improved tools and techniques for observation, prediction, and analysis of these storms and their associated hazards. In addition, NSSL works with social scientists and emergency responders in moving toward a Weather-Ready Nation that is resilient in the face of increasing vulnerability to severe weather. Part of this effort involves monitoring and quickly assessing damage in the wake of severe weather events such as tornadoes, so that emergency responders can be rapidly and efficiently dispatched to affected areas. In FY14 NSSL scientists evaluated several different methods that create preliminary damage paths of tornadoes as they occur and they utilized the results to develop a refined, automated method for creating radar-based tornado tracks during FY15. This new method was tested in collaboration with NWS forecasters and FEMA emergency responders in the Hazardous Weather Testbed. This work will be further refined and linked to FEMA databases in FY16.

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 interagency agreements
- 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 Subcommittees and Working Groups tab of the EMI-SIG website. 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 dispersion 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 has 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 Nuclear Regulatory Commission (NRC). RES provides technical support, 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. For example, RES is currently evaluating toxic gas dispersion modeling capabilities of several computer codes as licensing tools for assessment of control room habitability specific to dense gas release simulations. 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.

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

Interagency Collaborative Programs and Products

Integrated Water Resources Science and Services (IWRSS)

IWRSS is a new business model for interagency collaboration. IWRSS brings a consortium of United States federal agencies with complementary water resources missions together to share resources to help address the nation's water resources issues. These water resources 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. The collective capabilities of Federal water agencies need to be leveraged to inform and guide increasingly important water decisions.

Initiated through an Interagency Memorandum of Understanding (MOU), IWRSS's overarching objective is to enable and demonstrate a broad, interactive national water resources information system to serve as a reliable and authoritative means for adaptive water related planning, preparedness and response activities. The goals are to:

- integrate information delivery and simplify access to this data,
- increase accuracy and timeliness of water information, and
- provide summit-to-the-sea, treetop-to-bedrock, high resolution water resources information and forecasts for droughts to floods.

Currently the collaboration is with three United States federal agencies: USGS, NOAA, and USACE. Other federal agencies are expected to join the consortium in the near future. Two initial inter-agency teams have been established to support and help define the IWRSS effort; a National Flood Inundation Mapping team and a System Interoperability and Data Synchronization team. Teams have completed interagency requirements documents and are now working to establish designs to address identified requirements.

The activities of these two teams address the IWRSS goals, as well as the objective of the USACE *"Building Strong Collaborative Relationships for a Sustainable Water Resources Future"* initiative to build a Federal Support Toolbox for Integrated Water Resources

Management (IWRM). IWRSS builds on progress made under AHPS, CHPS and other NOAA water forecasting services. Additional information is included at http://www.nws.noaa.gov/oh/nwc/.

NOAA/National Weather Service

National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS; http://www.nws.noaa.gov/hdqrtr.php) has the primary responsibility among Federal agencies to provide advanced alerts of hydrologic conditions via flood warnings and river forecasts in the United States. The provision of these water prediction and warning services are significantly influenced by anthropogenic activities associated with water management and water use (e.g., reservoir regulation, diversions, withdrawals). In order to provide these important services, collaboration with other federal agencies is crucial as 24 Federal agencies have a role in water. The end-to-end forecast process employed by the NWS to provide hydrologic and water resources forecast and warning services leverages data and information from Federal partners and involves the following:

- Meteorological and hydrological observations and anthropogenic data;
- Data collection, management and processing;
- Science and technology infusion;
- River and water quantity forecasting;
- Inundation mapping;
- Dissemination systems;
- Performance measurement; and
- Outreach and education.

NWS relies on routine access to water data and observations from other Federal agencies to produce and provide water forecasts and warnings. These Federal agencies and their respective roles include the:

- Department of Interior (DOI)
  - U.S. Geological Survey (USGS) - real-time and historical streamflow observations, stream/river cross-sections, rating curves (relating streamflow to river stage), topographic data (for inundation mapping)
  - U.S. Bureau of Reclamation (USBOR) – water use/regulation data
- U.S. Army Corps of Engineers (USACE) – water use/regulation data, real-time streamflow observations, and hydraulic models
- U.S. Department of Agriculture (USDA) – snow observations
- Department of Energy (DOE) – water use/regulation data

The NWS hydrology and water resources program also leverages and expands NOAA science and service partnerships for the atmosphere, watersheds, estuaries, and oceans as well as partnerships with universities, the private sector, and the international community to improve and integrate modeling capabilities.

An NWS field infrastructure which includes 122 Weather Forecast Offices (WFO), 13 River Forecast Centers (RFC), the National Water Center (NWC), and the National Centers for Environmental Prediction's (NCEP) Weather Prediction Center (WPC) and Climate Prediction Center (CPC) work as a team to provide hydrologic forecast and warning services (see http://water.weather.gov/ahps/) from floods to droughts to minimize the loss of life and property and to meet the growing water resources service needs of our Nation. NWS hydrologic products and services support decision makers across a wide range of service sectors including emergency management, agriculture, hydropower, reservoir management, watershed management, river commerce, municipal and industrial water supply, and recreation.

A new element of the NWS water resources program infrastructure, the National Water Center (NWC), was completed in early 2014 on the campus of the University of Alabama in Tuscaloosa, AL. The NWC will serve as a cornerstone for collaboration among Federal water agencies and provide a central hub to integrate and advance regional field operations and services. It is currently being staffed to achieve an Initial Operating Capability by May 2015.

WFOs (http://www.nws.noaa.gov/organization.php) 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 NWC 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 work with dam operators and the emergency management community to provide timely warnings for floods that result from infrastructure failure such as dam break and levee breaches. Moreover, WFOs routinely conduct local outreach and education to heighten public and partner awareness of flood risks and NWS hydrologic services.

RFCs (http://www.nws.noaa.gov/organization.php) routinely generate short range (deterministic) through extended range (probabilistic) river forecasts and (deterministic) 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 WPC, CPC, NWC 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, NWC and the WPC.

NWC (http://www.nohrsc.noaa.gov/) provides comprehensive snow observations, analyses, data sets and map products for the Nation. NWC products and services are used by RFCs and WFOs to develop a variety of water resources products such as spring flood outlooks, water supply outlooks, river and flood forecasts, and reservoir inflow forecasts. Additionally, the NWC provides and supports geographic information system (GIS) data sets and applications used by the RFCs in generating automated hydrologic forecast basin boundaries. NWC 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 WPC, located in College Park, Maryland, routinely prepare a spectrum of analyses and forecast products spanning the period out to 7 days. The product suite is focused on heavy rainfall and heavy snowfall, and is used by the WFOs to develop local rainfall, snow, and ice forecasts. RFCs use the products to develop local river and flood forecasts. WPC coordinates with RFCs, WFOs and other Federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. In addition to the heavy precipitation focus, the WPC also provides an array of surface analyses and short-range forecast products, and medium-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 climate predictions and monitoring 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. Monthly Drought Outlook, a U.S. Seasonal Drought Outlook. CPC also 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. Please go to CPC's website, http://www.cpc.ncep.noaa.gov/, for more information.

The Community Hydrologic Prediction System (CHPS; http://www.nws.noaa.gov/oh/hrl/chps/index.html) is an operational framework that allows for broad systems interoperability at the 13 NWS RFCs, and supports 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 plans to 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 (ESP) - 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. The ESP capability is being expanded to include new techniques to facilitate the comprehensive generation of probabilistic hydrologic information seamlessly from short- to long- forecast horizons within CHPS. This enhanced capability is referred to as the Hydrologic Ensemble Forecast Service (HEFS) and is being implemented at select river forecast locations across the country.

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).

See Interagency Collaborative Programs and Products at the beginning of this section.

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 (OMAO)

Within the NOAA/Office of Marine and Aviation Operations (OMAO) aircraft fleet, the AC-695A Commander 1000 (N45RF) and a DHC-6 Twin Otter (N46RF or N48RF) are used

annually to conduct important snow-pack surveys (see http://www.nohrsc.noaa.gov/snowsurvey/) and soil moisture measurements throughout the U.S. 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 and soil moisture equivalent estimates. The data are transmitted to the National Operational Hydrologic Remote Sensing Center (NOHRSC; http://www.nohrsc.nws.gov/) 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

Snowmelt provides the majority of the annual water supply in the Western United States; therefore, having information on snowpack is critical for water supply forecasts and management. The Natural Resources Conservation Service (NRCS) measures snowpack and collects hydrometeorological data in 13 Western States, including Alaska. NRCS' Snow Survey and Water Supply Forecasting (SSWSF) Program conducts snow surveys at high elevations in the mountainous West. The data collection system includes approximately 1,112 active manual snow courses in the United States and Canada (Canada operates their own data collection, but shares data with US), and more than 878 automated Snow Telemetry (SNOTEL) and aerial markers (SNOLITE) monitoring stations. The NRCS collects data at the manual snow courses in cooperation with a number of different Federal, State, local, and private partners, as well as Canadian agencies. The SNOTEL and manual snow course 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. The purpose 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 automated SNOTEL and SNOLITE network transmits data from remote sites and is served on the web by the National Water and Climate Center in Portland, Oregon. The SNOTEL and SNOLITE 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 641 Western basins. All SNOTEL and SNOLITE data are provided hourly on the web and utilized by groups such as the National Weather Service (NWS) to assist in forecasting flood events. SNOTEL and SNOLITE 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, 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 the National Oceanic & Atmospheric Administration (NOAA). NOAA's National Operational Hydrologic Remote Sensing Center continues to support joint NWS-NRCS efforts. The NRCS typically develops nearly 12,000 seasonal water supply forecasts for 641 streamflow forecast locations in 13 Western States. In addition, the Program provides daily water supply guidance forecasts for 331 of the 641 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 to aid 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 snowpack conditions and timing of snowmelt, will increase the water supply challenges the States face. Monitoring data provides assistance to water managers at all levels to adapt to the impacts of climate change. Snowpack measurements extend back decades, and in some cases over 100 years, highlighting the value of this high-altitude network for understanding and assessing changes in climate.

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 Program, the NRCS also manages a cooperative nationwide network of 220 Soil Climate Analysis Network (SCAN) sites in 40 States, as well as Puerto Rico and the U.S. Virgin Islands. These SCAN sites monitor soil temperature and soil moisture, which support national drought monitoring, agriculture production, and climate change research. Presently, more than 430 SNOTEL stations also have soil moisture and soil temperature sensors.

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. The COE funds or partially funds nearly half of all the gages it uses.

The COE 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. 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.

Figure 1: The USGS has developed new rapidly deploy-able, mobile streamgages to provide short-term water-level data to critical areas lacking perma-nent streamgages. Image provided by USGS Office of Surface Water.

Near-real-time streamflow data and ancillary information are provided to NWS RFCs for river forecast locations and to general public for all USGS streamgages via USGS NWIS website (http://waterdata.usgs.gov/nwis/). Additional historical and real-time water resources data also are available. During floods, these data are supplemented by additional flood flow measurements.

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.

Nuclear Regulatory Commission

Following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011, Great Tōhoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) issued letters to all its operating nuclear power plant licensees requesting that they reevaluate the flooding hazards at their sites using updated information and present-day regulatory guidance and methodologies. This includes considering the effects from large precipitation events, snow pack, ice effects, and other meteorological events that drive flood events, such as storm surge. Licensees were directed to provide their responses on a set response date between March 2013 and March 2015 based on a set of criteria used to prioritize the nuclear power plant sites. The NRC staff, along with support from its consultants, has begun reviewing the flood hazard reevaluations and accompanying site-specific probable maximum precipitation analyses that have been submitted to date to determine whether additional regulatory actions are necessary to protect against the updated hazards.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

NOAA/Office of Oceanic and Atmospheric Research (OAR)

Hydrometeorological Testbed (HMT)

The HMT conducts research on precipitation and weather conditions that can lead to both flooding and drought, and fosters transition of scientific advances and new tools into forecasting operations. HMT's outputs support efforts to balance water resource demands and flood control in a changing climate. 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 at both the national (NCEP Weather Prediction Center) and regional (regional forecast centers and local forecast offices) levels. Research at the HMT, which operates as an end-to-end demonstration project with forecasters and researchers joining forces in the operational setting, has focused on improving regional forecasts of extreme precipitation, both too much and too little. This is achieved by a combination of: a) unique observations designed to monitor precipitation, kinematic, and surface processes; b) research aimed at improved understanding of physical processes leading to extreme precipitation; and c) operational forecast experiments to test new tools, methods, and models. HMT partners with organizations across NOAA, including NESDIS, OAR, NWS, NMFS, and NOS as well as regional academic and State authorities.

In FY16, ESRL/PSD will continue to operate and maintain major West Coast observing networks that are sponsored by the California Department of Water Resources (CA-DWR) and the U.S. Dept. of Energy through the Pacific Northwest National Laboratory. In California, there are four primary types of observing networks that are each designed to help forecasters and other end users monitor storm-scale and climate change impacts. In Oregon and Washington, the primary purpose of the observing networks is to aid with wind energy forecasting. ESRL/PSD will conclude the HMT Southeast Pilot Study (HMT-SEPS) and associated analysis efforts aimed at improving NOAA's ability to monitor and predict extreme precipitation in the southeast U.S. This work has and will (in FY16) result in presentations at international scientific meetings, such as those sponsored by AGU and AMS, as well as peer-reviewed publications. ESRL/PSD and HMT are also leading several projects in the California Russian River watershed as part of the NOAA Habitat Blueprint, aimed at sustaining healthy ecosystems. NSSL and HMT are conducting the HMT-Hydro testbed experiment in July of 2015 and 2016 in order to evaluate the latest developments in flash flood prediction tools and display software for endangered species ESRL/PSD will also implement an AWIPS-II development capability in FY16 to help foster the transition of HMT research products and data displays into operations.

Great Lakes Environmental Research Laboratory (GLERL)

GLERL conducts research and modeling to advance understanding of the hydrometeorological and hydrologic system of the Great Lakes basin. The Great Lakes is unique among hydrologic catchments worldwide in having about one-third of its area covered by fresh water, thus affording water a stronger second chance to evaporate while within a water body in addition to evapotranspiration from the land areas. Economic sectors such as fishing, shipping, and recreation are linked to the lake levels and water quality of the Great Lakes. A major product

from GLERL is the Advanced Hydrologic Prediction System (AHPS, different from the NWS product of the same name) that provides probabilistic outlooks on a seasonal time scale, based on the Climate Prediction Center's meteorological outlooks (and corresponding Canadian products), for lake levels, precipitation, river flow, and other variables. GLERL also has the Great Lakes Hydrometeorological Dashboard, a web-based system for displaying a wide variety of observational and model-generated data for lake levels, precipitation, ice cover, evaporation, and other variables. GLERL's hydrologic activities are coordinated with cooperating groups in both the operational and research realm through the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (CCGLBHHD, or "The Coordinating Committee"), including other US Government entities (US Geological Survey, US Army Corps of Engineers, EPA, and NOAA National Ocean Service) and the Canadian Government (Environment Canada).

National Severe Storms Laboratory (NSSL)

Storm-scale Hydrometeorology Research.

The Storm Surge Roadmap (SSR) provides a framework for a comprehensive NOAA strategy to holistically address the development of new technology, products and services to meet mission needs for storm surge and coastal total water level prediction. The SSR lays out the goals of NOAA's storm surge enterprise and identifies solutions to meet them. The SSR addresses coastal inundation from both tropical and extratropical cyclones over all areas of U.S. interest, including impacts of storm surge on the riverine environment. SSR outputs provide forecasters with the necessary tools to more accurately forecast the threat of coastal inundation; ensure the threat of dangerous water levels is communicated to the public in an understandable manner, thereby facilitating them in making better life- and property-saving decisions; and enable clear articulation of risk information to decision-makers and other partners, thereby resulting in a reduction of vulnerability to risks associated with coastal inundation. The SSR project portfolio lays out how new storm surge technologies, products, and services will be developed to meet specific strategic objectives.

NSSL contributes within this framework through the Coastal and Inland Flooding Observation and Warning (CI-FLOW) project, a multi-organizational, inter-disciplinary research and development project led by NSSL focused on improving NOAA's prediction of total water level within tidally influenced watersheds. A real-time coupled model system that captures the total water level (tides + waves + storm surge + runoff) was developed through the CI-FLOW project. The modeling system couples precipitation estimates (NSSL's Multi-Radar/Multi-Sensor system), a hydrologic model ensemble (NWS's Hydrology Lab – Research Distributed Hydrologic Model), a storm surge model [ADvanced CIRCulation (ADCIRC) model], and a wave model (Simulating WAves Nearshore model) to obtain flood inundation extents and significant wave heights. The CI-FLOW project successfully tested the coupled modeling system in real time on Hurricane Earl (2010) and Hurricane Irene (2011) in the Tar-Pamlico and Neuse basins in North Carolina. NOAA's NWS, NOS, and OAR are synchronizing forecast capabilities to develop a national operational water forecast system. CI-FLOW is playing an active role in NOAA strategic planning for coupled river modeling by communicating research results learned throughout the history of the project.

NSSL is working with the NWS to bring enhanced weather information and capabilities to operations. After more than a decade of development, testing and experimental evaluation,

NSSL, in collaboration with the National Center for Environmental Prediction (NCEP), has delivered the Multi-Radar/Multi-Sensor (MRMS) system to NWS operations. MRMS consolidates and "cleans up" data from a wide variety of sources including radars, satellites, and surface observations to provide forecasters with the best-possible real-time analysis of the atmosphere at any location. This system has shown considerable improvement in radar-based rainfall estimates and provides forecasters with an ability to "mine" the data set to extract new types of aviation, severe and hydrologic weather information. By placing high-quality, remotely-sensed data in a three-dimensional framework accessible to NWS forecasters, MRMS has opened the door to exciting new possibilities in improving flash flood and severe weather warnings, as well as forecasts.

The MRMS suite of quantitative precipitation estimates (QPEs) incorporates information from operational and research weather surveillance radars (e.g., NOAA/NWS WSR-88Ds, FAA Terminal Doppler Weather Radars, deployable "gap-filling radars, Canadian operational network radars, etc), GOES satellite data, lightning flash detections, rain gauge accumulations, surface and upper air observations, and numerical model outputs to produce gridded precipitation estimates. These precipitation products, with their different levels of complexity, each have strengths and weaknesses that vary with season, geography, and precipitation type. The MRMS QPE algorithm is unique in the way that it uses dual polarization moments to improve the quality of the precipitation maps, automatically identifies the precipitation type at each grid point, applies differential Z-R relationships, corrects for the vertical profile of reflectivity, merges radar-based estimates with rain gauges, and estimates surface precipitation type. The proven accuracy and unprecedented high-resolution of the MRMS QPEs enables them to be used as forcing to a state-of-the-science flash flood prediction system.

The Flooded Locations And Simulated Hydrographs (FLASH) project takes advantage of the MRMS QPEs that capture rainfall at flash flood scale. The rainfall estimates are used to produce a suite of flash flooding products including the ratio of QPE-to-flash flood guidance, rainfall average recurrence interval, and streamflow forecasts from the Ensemble Framework for Flash Flood Forecasting (EF5). EF5 yields forecasts of flash flooding using two different water balance configurations out to 6 hours in the future at every grid point in the conterminous US. FLASH is presently running in real-time and will be transferred to NWS operations using the MRMS research-to-operations conduit. FLASH outputs have been evaluated by forecasters during the Flash Flooding and Intense Rainfall (FFaIR) testbed experiment at the Weather Prediction Center in 2013, the Hazardous Weather Testbed-Hydro experiment in 2014 and now during the Hydrometeorological Testbed-Hydro experiment in 2015. Objective evaluations of EF5 outputs have been conducted and show excellent skill in simulating peakflows in gauged basins. Given that the model parameters are based on observable features of the land surface, the same performance is to be expected in ungauged regions. The FLASH system offers an accurate, consistent, nation-wide solution for flash flood forecasting by the National Weather Service.

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 methods used to estimate the effects of extreme precipitation events, evaluating the use of paleoflood information to extend the historical record, and applying probabilistic techniques to riverine systems. The extreme precipitation work has been extended to consider the influence of orographic features. In addition, work has been initiated to start looking at flooding, including site-specific probable maximum precipitation, from a probabilistic perspective. Preliminary planning is underway to develop an integrated probabilistic approach for flood hazard assessment for nuclear power plants that will include advanced approaches for modeling meteorological and hydrological phenomena and systems. 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, or where existing nuclear power plants have submitted analyses for the NRC to review. 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, as well as other experts such as FERC, and the national lab system. 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 organizations enable DoD decision-makers to anticipate and exploit the weather for air, ground, space, cyberspace, and intelligence operations. AF weather personnel provide mission-tailored terrestrial and space environment observations, forecasts, and services to the U.S. Air Force (USAF), U.S. Army (USA), and a variety of U.S. Government departments and agencies.

The AF Director of Weather (AF/A3W) is aligned under the AF Directorate of Operations (AF/A3), Headquarters Air Force. The Director of Weather is responsible to organize, train and equip AF weather organizations, to include the following functions:

- Development of doctrine, policies, requirements, and standards for weather support for worldwide Air Force, Army, and Special Operations training and contingency operations
- Evaluation of weather support effectiveness for worldwide training and contingency 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 Operations, 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 contingency operations

AF weather operations operate with the Total Force concept, employing more than 4,000 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 AF weather personnel are focused on two distinct, yet related functions: characterizing the past, current, and future state of the natural environment, and exploiting environmental information to provide actionable environmental impacts information directly to decision-makers.

Weather personnel must understand the tactics, techniques, and procedures of the supported military unit, and help decision-makers take advantage of favorable weather conditions or mitigate unfavorable weather effects. AF weather personnel support Air Force, Army, Joint, and DoD conventional and special operations at various garrison and deployed locations worldwide.

AF weather personnel aligned with Army units directly support all aspects of Army ground and aviation operations, to include integration into the G-2 intelligence centers and Army Fire Support operations. Weather is a vital part of the intelligence estimate and is an essential element that supports the military decision-making 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 AF weather 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. AF weather forces are organized in a 3-tier structure to maximize capabilities that can be accomplished in the rear area via "reach-back" technology. This minimizes forward presence on the battlefield, making a "light and lean" presence consistent with the overall USAF vision for contingency operations in the 21st century.

557th Weather Wing (557 WW). The Air Force Weather Agency (AFWA) was re-designated the 557th Weather Wing in March 2015 as part of an Air Force-directed realignment effort. The 557 WW is a special-mission wing aligned under Air Combat Command. It is the weather production center of the USAF in the first tier of the AF weather organizational structure. The 557 WW delivers worldwide weather products to Air Force and Army units, unified commands, National Programs, and the National Command Authorities. The 557 WW 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. Additionally, they build and maintain the world's most comprehensive weather database of observation, forecast, climatological, and space weather products available to DoD personnel on the World Wide Web. Under the AF weather 3-tier structure to support forward operations via reach-back technology, The 557 WW'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.

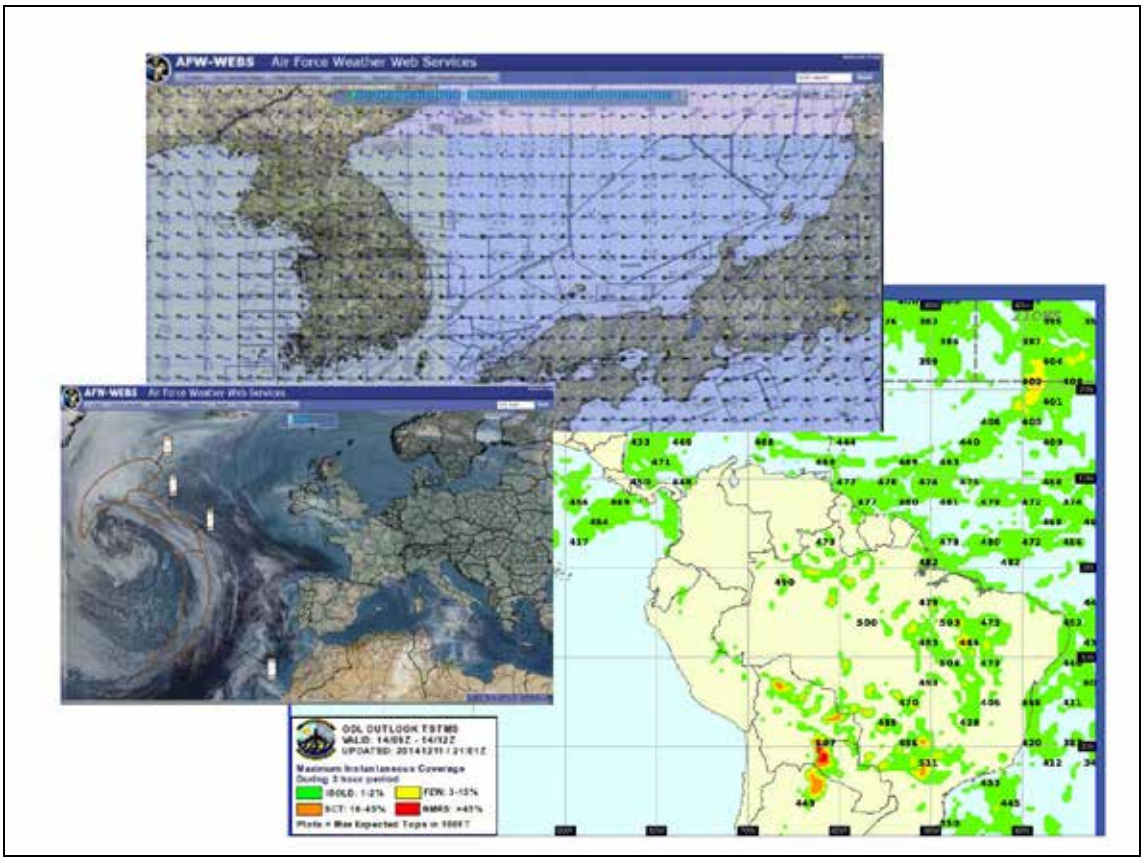


Figure 1: Example of Air Force weather support products.

- The 1st Weather Group (1 WXG) aligns weather operations with the USAF warfighting initiative overseeing the OWSs. The 1 WXG has six subordinate OWSs whose areas of responsibility are aligned with the Geographic Combatant Command areas of responsibility. They form the backbone of regionally focused, "reach-back" weather operations around the world, 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 (2 WXG) 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 the USAF's $288 million strategic center computer complex, production network, and applications.

Additional overview: http://www.557weatherwing.af.mil/shared/media/document/AFD-150325-016.pdf

Operational Weather Squadrons. Around the world, the OWSs are the second tier of the AF weather 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 149 installations/sites in a 22-state region of the northeastern United States.
- The 17th OWS's area of responsibility covers more than 95 million square miles of the Pacific region including Alaska, Hawaii, Australia, Guam, 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 79 installations/sites in an 11-state region of the western United States as well as support to the U.S. Southern Command area of responsibility.
- The 26th OWS's area of responsibility includes 133 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 Egypt.

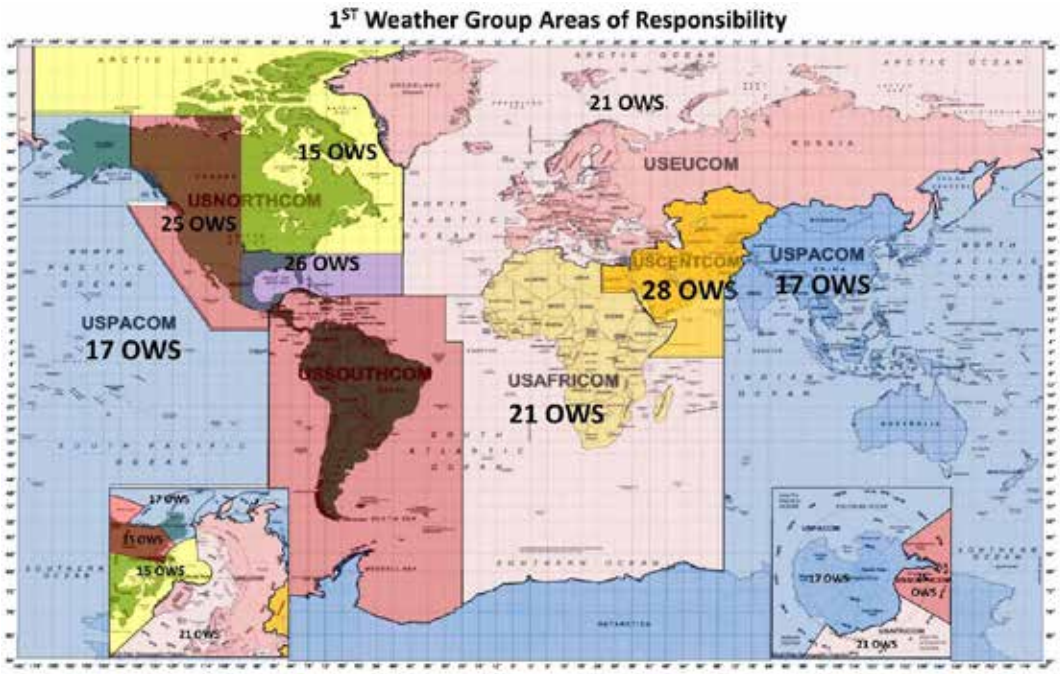


Figure 2: Operational Weather Squadrons assigned to 1st Weather Group are aligned with Geographic Combatant Commander's Areas of Responsibility (AORs).

Weather Flights. At the installation-level or deployed in the field and focused on tactical weather support, USAF Weather Flights constitute the third tier of AF weather organizations and act as the primary 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 while providing tailored, mission-specific forecast products to their supported units on the installation.

Special Operations Weather. USAF special operations weather teams (SOWT) 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. The tailored weather information and knowledge provided enable planning, decision-making, and execution of SOF operations. USAF SOWT assigned to SOF units are expected to know and keep current on the

entire environment in the isolated locations to which their unit deploys. They provide mission execution forecast products to all Army special operations ground and aviation units.

USAF Weather Support to Conventional Army Operations. Weather Airmen aligned with Army units predict the effect weather will have on Army and joint operations, giving leadership at all levels the ability to adjust operational and tactical strategies to ensure mission success. Weather technicians and meteorologists assigned to support Army units are expected to forecast the weather anywhere their Army unit deploys. Air Force weather personnel supporting Army operations are trained in the basic and specialized soldier skills required to support their aligned Army unit, which could include the ability to 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 mission 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. USAF 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 USAF 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 USAF space weather operations and the National Weather Service's (NWS) Space Weather Prediction Center, see the section on Space Weather Services.

USAF Reserve Component. The Reserve Component includes weather Airmen in both the Air Force Reserve Command (AFRC) and the Air National Guard (ANG). The USAF continues to integrate these forces to more closely align with active duty weather 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 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.

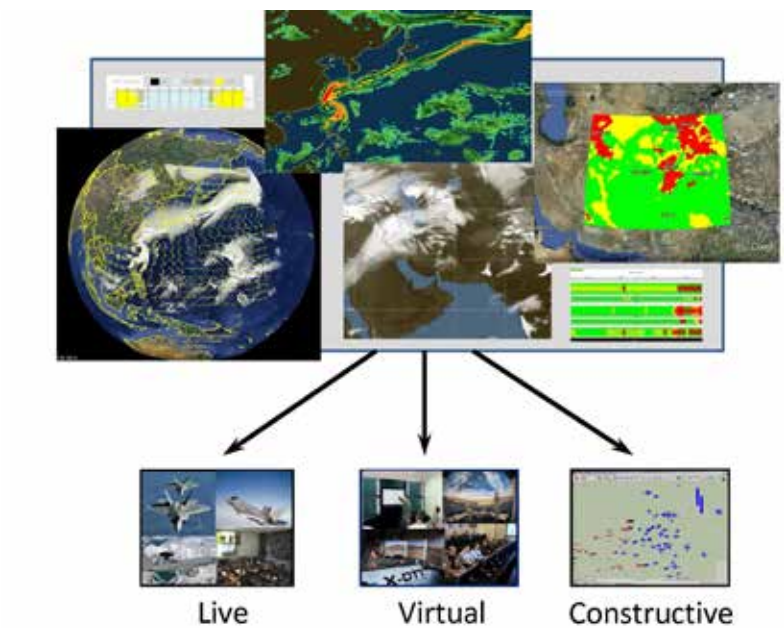
The ANG traditional program consists of 27 numbered weather flights, ranging in size from 13 to 25 personnel, who meet monthly to train for their wartime mission. These flights provide weather support to ANG and Army National Guard units. Air Combat Command (ACC)-gained ANG wings also have up to four 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 it is responsible for providing peacetime weather support to airfield operations.

Air Force Products and Services

Satellite Services. The USAF 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 5 decades. Onboard sensors provide AF weather organizations 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, the USAF receives stored data from NOAA's operational polar-orbiting geostationary environmental satellites; European METSAT (EUMETSAT) geostationary and polar-orbiting satellites, as well as the primary Japanese geostationary meteorological satellite. (The USAF currently receives data from the National Aeronautics and Space Administration's (NASA's) 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).



Four-dimensional weather scenarios provide realistic simulations of weather effects on operations and are integrated into live, virtual and constructive (LVC) training.

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

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 that use simulations for their training, acquisition, testing, planning, experimentation, and analysis have the right tools, infrastructure, and databases necessary to represent the air and space natural environment and its effects.

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

The 53rd Weather Reconnaissance Squadron "Hurricane Hunters," gathering atmospheric data to relay to the National Hurricane Center for their forecast models. (U.S. Air Force photo by Staff Sgt. Valerie Smock)

Air Force Aviation Weather Support. As previously discussed, 1st Weather Group (1 WXG) has six subordinate OWSs that form the backbone of regionally focused, "reach-back" weather operations, providing a variety of weather forecast products and support to units assigned to and/or deployed into their supported areas of responsibility (AORs). These OWSs provide operational weather support and resource protection for personnel and military installations in their respective AORs around the globe. Operational support to the USAF, Army, Navy, Marine, Guard, Reserve and regional Combatant Commanders includes graphical analysis, aviation terminal aerodrome forecasts, severe weather watches/warnings and advisories, and mission execution forecasts, such as aviation hazards and en route 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 557 WW 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, AF weather flights or detachments focus on their supported unit's mission requirements. These weather personnel provide and disseminate observations and develop tailored mission execution forecasts based on centrally produced guidance. For AF operations, these weather professionals are normally assigned to a flight under an operations support squadron of an AF flying wing; however, individuals from the weather flight are integrated into flying squadron mission planning and execution processes. For Army operations, the AF weather personnel typically fall under an air support operations group (ASOG) and are integrated into all echelons of Army operations, from the corps down to the brigade combat team level. In this capacity, weather personnel supporting AF and Army aviation operations infuse critical weather information at key points in decision-making cycles to help decision-makers maximize wartime capabilities, enhance flight safety, and optimize training effectiveness.

Volcanic Ash Surveillance and Analysis. One of the roles of the 2nd Weather Group is to provide volcanic ash surveillance and analysis for DoD aviation operations worldwide. Analysts continuously monitor all active volcanoes, generating more than 3,500 bulletins per year. Tailored satellite imagery, graphical ash plume forecasts, 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.

Air Operations Center Support. AF weather personnel are aligned under the combat operations division of air operations centers. This flexible weather support element integrates environmental information at key decision points of air and space operations planning, execution, and assessment. Armed with this information, decision-makers can balance operational risks against mission need to optimize timing, tactics, target and weapons selection, and other factors affecting air and space operations.

Education and Training. USAF officers newly accessed into the weather career field are university graduates with degrees in meteorology/atmospheric science. Further, the USAF sends approximately ten officers per year to obtain advanced degrees, both M.S. and Ph.D., through the Air Force Institute of Technology. New enlisted weather personnel attend the rigorous nine-month Weather Apprentice Course at Keeler AFB, MS. At their first weather duty assignment, they gain a combination of operational experience and further skill upgrade training in

accordance with the enlisted weather career field education and training plan. Continuation training programs for both officer and enlisted personnel ensure continuous learning appropriate to the supported mission and location. This education and training process ensures Air Force weather personnel possess both breadth and depth of meteorological knowledge and experience supporting atmospheric and space weather collection, prediction, analysis, tailoring, integration and risk management processes as they apply to employment of multiple weapon systems and capabilities for both the Army and the Air Force.

Air Force Aviation Weather Products and Services

NextGen Development. The USAF weather function 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. Air Force Weather Ensemble Prediction System (AFWEPS) is also providing valuable path-finding insight into the utility and delivery of probabilistic aviation impacts that is a requirement for NextGen.

Weather System Upgrades. In FY 2016, the USAF will continue to upgrade weather systems and processes that support all DoD aviation. Continued refinements of the Joint Environmental Toolkit along with 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 United States Army (USA)–United States Air Force (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 multi-Service regulation describes the responsibilities of USAF and USA 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 Air Force weather personnel to provide direct and indirect weather support to the Army Commands, Army Service Component Commands, 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. Each Service provides this support on a non-reimbursable basis.

Air Force Weather personnel provide installation, garrison, and tactical weather support on a daily basis to 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. U.S. Army Space and Missile

Defense Command/Army Forces Strategic Command (SMDC/ARSTRAT) 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, Army Commands, and Army Service Component Commands

Headquarters, Department of the Army (HQDA) The Office of the Deputy Chief of Staff, G-2, employs two civilian meteorologists whose primary duties are to establish weather policy within the Army, coordinate on AF weather policy issues with the Air Force Director of Weather (HQ USAF/A3/5), submit approved Army weather requirements and priorities to the HQ USAF/A3/5, coordinate with the AF on Army-AF and Joint Service weather operational concepts and doctrine, serve as the Army staff lead for meteorological satellite capabilities and issues, and review and coordinate Army-related support issues with the Office of the Secretary of Defense, the Joint Staff, the Department of the AF, other Services, HQDA staffs, Army Commands, Direct Reporting Units, Army Service Component Commands, and other Federal Agencies. FY 2015 activities will focus on meteorological satellite activities, coordination of meteorological activities within the Army, and development of DoD level policy with the Services, Joint Staff, and OSD.

The Office of the Deputy Chief of Staff, G-3/5/7 (DCS, G-3/5/7), approves 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 on Army weather program and resource issues, and Army installation weather support requirements.

Project Manager Distributed Common Ground System – Army (PM DCGS-A) is a materiel developer of weather capability in the Army and reports to Program Executive Office Intelligence, Electronic Warfare and Sensors (PEO IEWS) and Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)). DCGS-A work stations are provided to Air Force weather personnel to tailor current and forecast weather information into specific weather effects across the warfighting functions for exploitation in intelligence and operations processes. In addition to developing, integrating, testing, and fielding capability, PM DCGS-A also leverages Air Force weather capability in support of Army operations.

Training and Doctrine Command. Headquarters, TRADOC, is responsible for leading the USA in development of and validating requirements for all Army weather capabilities and specifically for USA-USAF inter-Service weather operations, services concepts, and doctrine required in support of 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 approval as required. TRADOC's Army Weather Proponent Office (AWPO) 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 from TRADOC centers and schools.

Key mission areas for the next few years: (1) assist the TRADOC equivalent USAF weather command with development and implementation of a new weather support concepts to meet the needs of the USA and USAF's evolving force structures; (2) update Army and multi-service

weather support doctrine, policy, organization, concepts, along with tactics, techniques, and procedures with the equivalent USAF command; (3) ensure weather lessons learned and after action concerns with AF weather support to USA operations are documented, communicated, and resolved between Army and Air Force organizations to positively influence doctrine, organization, training, material, leadership education, policy, and facilities (DOTMLPF); and (4) ensure USA weather support processes and procedures are trained across the TRADOC schools and centers. These mission areas are accomplished in coordination with the equivalent USAF Weather organization and TRADOC.

U.S. Army Intelligence Center of Excellence. The U.S. Army Intelligence Center of Excellence (USAICoE) is the TRADOC Army Weather Proponent Office (AWPO) for USA tactical weather support. As such, TRADOC's AWPO 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 AWPO 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. The AWPO employs one Department of the Army Civilian (DAC) to lead these weather requirement efforts. This DAC oversees the AWPO efforts with the JCIDS process, and in all 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 Aviation Center of Excellence (USAACE). USAACE provides 10 courses in the aviation training curriculum that contain weather training for aviators and unmanned aircraft systems operators. USAACE is in the process of acquiring excess automated surface observing systems from the Air Force to enhance flight safety at several training airfields.

Artillery Meteorological Education and Training. The U.S. Army Fires Center of Excellence is the proponent for artillery meteorological education and training. Computer Meteorological Data- Profiler (CMD-P) (AN/GMK-2) is a weather measurement system developed to provide meteorological (MET) data to support artillery and target acquisition units. The AN/TSR-8 Global Broadcast Service (GBS) Satellite Receiver Suite receives polar orbiter MET data & communications satellite data and Operational Global Atmospheric Prediction System (NOGAPS) initialization data via a GBS satellite link. CMD-P provides MET data messages covering up to 500 km from the Profiler's position. The CMD-P interfaces with the Advanced Field Artillery Tactical Data System (AFATDS) via Local Area Network (LAN) connection and is operated by the AFATDS Operator 13D. In the future, the system will no longer require the GBS receiver suite as part of a profiler system but will rely on the GBS connection from the TOC LAN (MET data is downloaded on Compact Disc via internet from the 557th Weather Wing). 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. These MET messages will be tailored to the mid-point of the trajectory for enhanced accuracy.

U.S. Army Test and Evaluation Command (ATEC). ATEC is responsible for providing operational meteorological support to USA RDT&E ranges. Under responsibilities established in AR 115-10/ AFI 15-157 (IP), ATEC meteorological units provide meteorological data collection

and analysis, and consultation to support USA and other DoD RDT&E activities at seven ATEC ranges. The Meteorology Division at West Desert Test Center, located at Dugway Proving Ground, is the technical lead for the ATEC Meteorology Program.

U.S. Army Space and Missile Defense Command/Army Forces Strategic Command Support to the Ronald Reagan Ballistic Missile Defense Test Site. A subcommand of SMDC/ARSTRAT 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.

U.S. Army Products and Services

U.S. Army Artillery. The Profiler Block III provides highly accurate meteorological data to the Advanced Field Artillery Tactical Data Systems (AFATDS) to adjust artillery fire. The system supports battalion and brigade Field Artillery units. The Profiler Block III is connected to the Tactical Operations Center local area network and provides the Advanced Field Artillery Tactical Data Systems (AFATDS) with the meteorological requirement for achieving first round hits and fires for effect. The Profiler Block III uses weather data obtained from the Air Force through Mission Command networks. It provides meteorological on demand with or without an operator in-the-loop to the AFATDS. A virtual module product improvement is currently under development and will be available in FY16 with an upgraded weather model and changing the software to be Common Operating Environment compliant.

Distributed Common Ground System–Army (DCGS-A). Weather Services. DCGS-A weather services enables the Staff Weather Officer and intelligence operators to integrate weather effects in Intelligence Preparation of The Battlefield, Military Decision Making Processes, and Mission Command. DCGS-A exploits AF weather capability through reach-back, utilizes DCGS-A tools/applications, employs Ozone Widget technology, and Data Distribution Service to distribute weather information to users throughout the enterprise.

U.S. Navy

Operational Organizations

Oceanographer of the Navy. Naval Oceanography encompasses Meteorology and Oceanography (METOC), Geospatial Information and Services (GI&S), Precise Time and Astrometry (PTA) under the sponsorship of the Chief of Naval Operations (CNO). The Oceanographer of the Navy (OPNAV N2/N6E) is the Secretary of the Navy and Chief of Naval Operation's principal advisor for Meteorology and Oceanography (METOC), Maritime Domain Awareness, Navy Space, Positioning, Navigation, and Timing (PNT), and performs functions relating to external interfaces with national and international operational and research and development oceanographic organizations and activities.

The Oceanographer and Navigator of the Navy, serves as the focal point for matters related to the Naval Oceanography enterprise (NOe), the Arctic region, and other marine science fields. The Oceanographer and his staff work closely with Information Dominance Type Command (IDFOR), U.S. Fleet Forces Command, Pacific Command (USPACOM), and the Office of Naval

Figure 3: Rear Admiral Jonathan W. White (OPNAV N2N6E) Oceanographer and Navigator of the Navy; *Official U.S. Navy Photograph*

Research to ensure the proper resources are available to meet operational requirements. As the functional manager for 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 Department of Homeland Security (DHS) for strategic METOC and PNT programs. He acts as Naval Deputy to the NOAA Administrator and represents the Naval Oceanography Program in interagency and international forums.

The Navigator of the Navy provides guidance and standardization of METOC, maritime geospatial information, astrometric and precise-time models, databases, and environmental predictive techniques through the Oceanographic and Atmospheric Model Library (OAML). He coordinates NOe policy and architectures throughout 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 (R2O) applications. This integrated approach provides the Fleet and System Commands (SYSCOM) with critical information about the physical environment and its impacts on platforms, sensors, weapons, and personnel. 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).

In 2014 CNO established the Information Dominance Forces Command (IDFOR) the Navy's newest TYCOM on 29 August 2014. IDFOR integrates weather into the intelligence pillars of

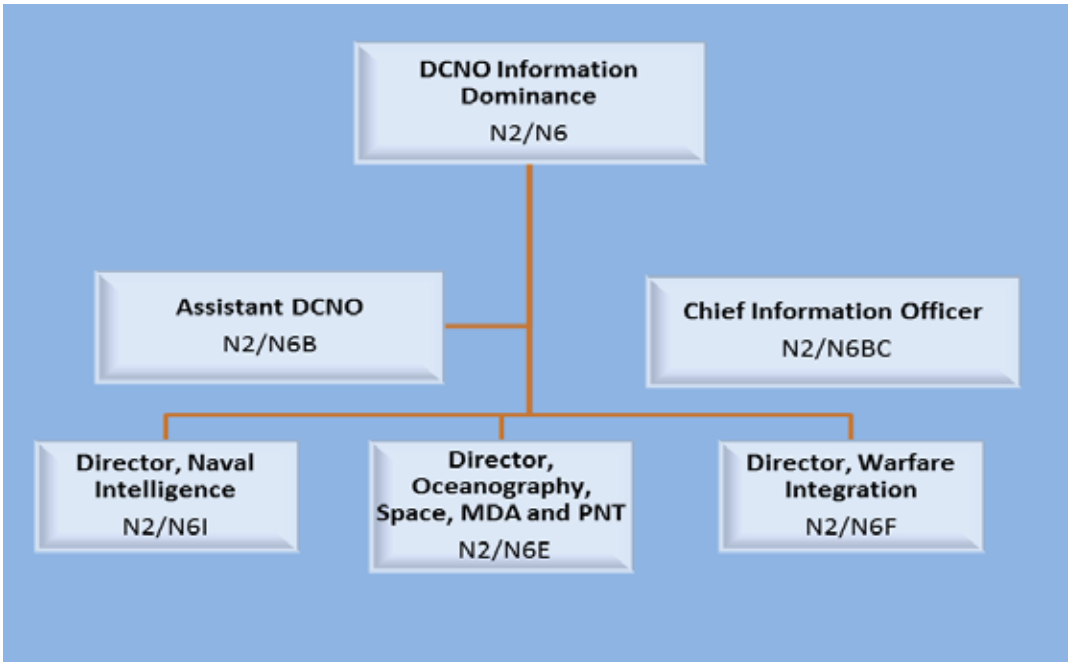


Figure 4: Organization of the Deputy, Chief of Naval Operations (DCNO) for Information Dominance (OPNAV N2N6) showing placement of the Oceanographer and Navigator of the Navy, as the Director, Oceanography, Space, and Maritime Awareness, and PNT.

Battlespace Awareness, Assured Fires, and Assured Command and Control. With this integrated man, train and equip (MT&E) portfolio, IDFOR will coordinate closely with the aviation, surface ship, and submarine platform TYCOMs to deliver enhanced Information Dominance capability and readiness to the fleet.

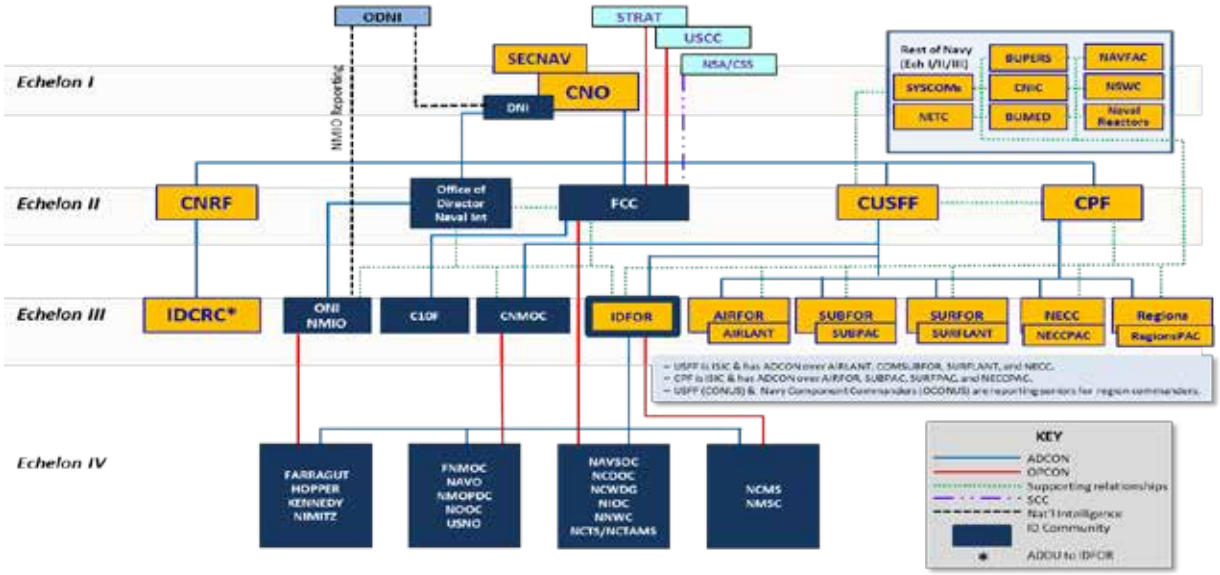


Figure 5: The Information Dominance Forces Command (IDFOR) with its Naval Linkages

This Command and Control (C2) preserves CNMOC as the Operational Commander which leaves echelon IV operations largely unchanged, and the focus of upcoming Implementation is to define and exercise the processes that will support the TYCOM's mission, functions, and tasks (i.e., Manpower, Equipment, Training, Financial Operations, and Readiness Reporting). Administrative Control (ADCON) for above tasks shifts from CNMOC to TYCOM though some residual capability will exist at CNMOC to directly facilitate operations.

Task Force Climate Change (TFCC). 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. The National Strategy for the Arctic Region signed in 2013, recognizes that the Arctic is opening up for human enterprise, energy resources and will continue to increase as a strategic priority for the United States and Navy.

The U.S. Navy Arctic Implementation Plan was issued in February 2015 and prepares the U.S. Navy to respond effectively to future contingencies, delineates the U.S. Navy's Arctic Region leadership role within the Defense Department, and articulates the Navy's support to national priorities. The Arctic and climate change Roadmaps provide all encompassing, chronological, science-based guidance for future Navy operational and action from 2014 through 2030.

- Arctic Observation/Prediction International Engagement Plan
  - ONR leading development effort through Interagency Arctic Research Policy (IARPC) Committee
- Arctic Sensing Plan

- R&D collection efforts ongoing
- OPNAV developing sensing strategy => POM 17

- Improve Modeling/Prediction of Arctic Environment
  - ONR funding R&D of long-range Arctic models
  - NRL sea ice prediction model

Naval Meteorology and Oceanography Command. The Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) is responsible for the Command and management of the Naval Oceanography Program (NOP) utilizing meteorology and oceanography, GI&S, and precise time and astrometry, to leverage the environment to enable successful strategic, tactical and operational battle space utilization across the continuum of campaigning and at all levels of war: strategic, operational and tactical. COMNAVMETOCCOM will retain administrative control (ADCON) over the METOC fourth echelon commands, reporting to the Information Dominance Typer Command (IDFOR), and serving as the operational arm of the NOe. COMNAVMETOCCOM's assets are globally distributed at shore facilities in fleet concentration areas.

Two central METOC Production Centers are located in the U.S. and operate through the Naval Oceanography Operations Command (NAVOCEANOPSCOM) at the Stennis Space Center (SSC) in Mississippi. As the Navy's physical science team, Naval METOC personnel (Navy and Marine Corps) are highly educated sailors, marines, and civilians that measure and collect meteorological, oceanographic, hydrographic and other data relevant to the physical battlespace. They use the data to analyze and determine current conditions, forecast the future state, and provide mission-focused impacts that enable commanders to make well-informed operational decisions across the entire spectrum of warfare. Operational oceanography operates along eight distinct lines of operations: maritime operations, aviation operations, fleet operations, navigation, precise time and astrometry, expeditionary warfare, anti-submarine warfare, and mine warfare. Maritime operations enable the safe operation of ships and submarines at sea through individualized forecasts, monitoring of their movement relative to hazardous weather, and alternate route advisories as warranted. Aviation operations are similar, but focus on the safe navigation of aircraft. Fleet operations represent our oceanography forces deployed on aircraft carriers, amphibious assault ships, independent deployers and task forces. METOC and Navigation services enable safety of surface and subsurface operations and support the Global Positioning System, networks, communications, and space-based systems. Expeditionary warfare (amphibious warfare, riverine warfare and special operations), antisubmarine warfare, and mine warfare (offensive mining and defensive countermeasures and clearance), as their names imply, support their respective warfare areas via a mixture of forward-deployed and reach-back capabilities required to provide intelligence preparation of the operational environment (IPOE). 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 the following:

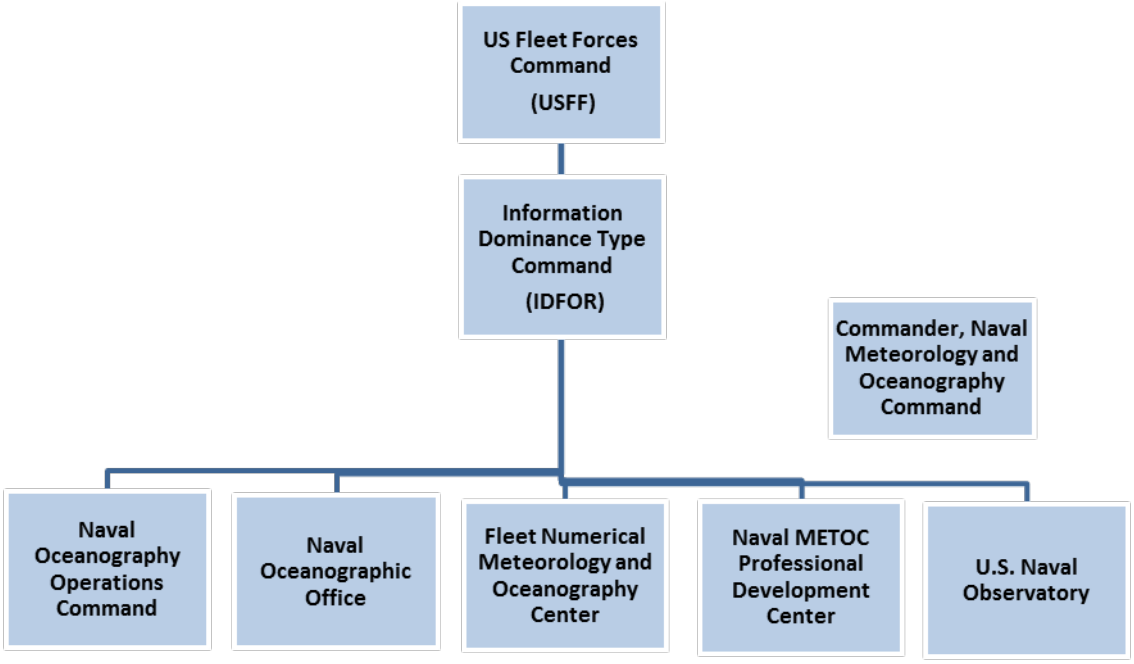


Figure 6: Organization of Naval Meteorology and Oceanography Command within the U.S. Fleet Forces Command structure

- 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 METOC 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 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 operations support portion of USN/USMC 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, is an 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. Since the end of the Navy's Geosat Follow-On (GFO) satellite, the military has been reliant on the Ocean Surface Topography Mission for radar altimetry, a unique source for atmospheric, oceanographic, and geodetic data. Navy is working with NOAA to find partnership opportunities through the JASON radar altimetry program. Through close collaboration with NAVOCEANO, FNMOC is also a key component in the Navy's operational weather and ocean prediction program. Naval operational oceanography is the key contributor to providing the predictive, physical maritime battlespace awareness capability. In the future, vital information from both intelligence and oceanography professionals will be fused into the same common operational picture afloat, providing a view of the battlespace we can only imagine today, ensuring better and faster warfighting decisions.

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 ocean-class hydrographic survey vessels and data from both aviation assets and spacecraft NAVOCEANO is headquartered at the Stennis Space Center, which is home to the Navy Department of Defense Supercomputing Resource Center that Navy, Army, and Air Force scientists and researchers use to design tools and weapons systems that support the Department of Defense's global mission. The Navy DSRC is a premier provider of high performance computing services and support to DoD scientists and engineers. It is one of five supercomputing centers established under the DoD High Performance Computing Modernization Program (HPCMP). CNMOC maintains oversight of the Navy DSRC systems that have been operational since 1997.The Navy DSRC provides a high performance computing capability with primary

Figure 7: NAVOCEANO makes use of many Unmanned Autonomous Vehicles for data collection

emphasis on support of the largest, most computationally-intensive HPC applications. Our center leads the way for numerous HPCMP-wide initiatives and provides our users with in-depth computational expertise and support. While the HPCMP is primarily focused on DoD research and development programs, the Navy DSRC is unique in that approximately 15 percent of its total capability is apportioned for operational use by naval operational oceanography. Today, the Navy DSRC enables, on a daily basis, operational, global, regional, and port scale ocean circulation, as well as wave and sea ice forecast numerical models supporting worldwide Navy and DoD operations. Navy DSRC's total computational capacity affords us computational space to not only improve our ocean models, but to bring online world-class atmospheric models within the DSRC and begin to more tightly couple ocean and atmospheric physics and energy exchange to provide a more accurate, longer range future state of the atmosphere.

Navy Products and Services

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 Region 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.

Figure 8: AGC Timothy P. Crowley seeding the currents with data collection capabilities to feed the oceanographic models and to help with para-rescue operations in the Horn of Africa AOR.

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. Navy and 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.

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. FNMOC employs four primary models—the Navy Global Environmental Model (NAVGEM), 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.

- NAVGEM is an improvement to the former Navy Operational Global Atmospheric System (NOGAPS) 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 NAVGEM. 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 NAVGEM. It is used to forecast tropical cyclone tracks globally.
- WW3 is a spectral ocean wave model that is employed both globally (driven by NAVGEM) and regionally (driven by COAMPS) in support of a wide variety of naval operations.

FNMOC Products and Services. FNMOC's complex and robust operational prediction capability is designed to deliver detailed forecasts of wind stresses and heat fluxes to drive very high-resolution ocean models 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. 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 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.

Figure 9: AG1 James Patterson with the 82nd Expeditionary Rescue Squadron, preparing a forecast.

Many of FNMOC's products are distributed to users over the Web via the PC-based METCAST system, and subsequently displayed and manipulated on the user's PC with the Joint METOC Viewer (JMV) software. This includes all standard METOC fields, synoptic observations, and satellite imagery. 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 in 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. 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. 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 NAVGEM and COAMPS atmospheric models.

U.S. Marine Corps

Operational Organizations

CMC, DC/AVN, APX-9. The senior USMC METOC officer is dual-hatted as the METOC Services Officer and the METOC Occupational Field (OccField) Sponsor. The billet resides within the Aviation Department, Headquarters, U.S. Marine Corps, Washington D.C. and is physically located in the Pentagon, Aviation Expeditionary Enablers (APX) branch.

The METOC Services Officer is the principal advisor and subject matter expert to the Deputy Commandant, Aviation. The Aviation Department mission is to assist and advise the Commandant of the Marine Corps on all matters relating to Marine Aviation consistent with Marine Corps requirements. Specific duties include, but are not limited to: advise the Commandant of the Marine Corps on aviation safety, aviation policies, and Joint matters relating to aviation; provide principal aviation staff interface with the Chief of Naval Operations (CNO); ensure Marine Corps Aviation operates in compliance with Naval Aviation directives and programs; member of the Joint METOC Board Executive Steering Group; member of the Battlespace Awareness Functional Capabilities Board; member of the Joint Capabilities Board; USMC liaison to the National Oceanic and Atmospheric Association and the Office of the Federal Coordinator for Meteorology.

The METOC Occupational Field Sponsor establishes policies and procedures for the effective management of officers and enlisted Marines serving in METOC billets across the MAGTF and supporting establishments.

Marine Liaison, Oceanographer of the Navy (N2/N6) The United States Marine Corps Liaison and Requirements Officer responsible for the funding of all programs associated with METOC support to the MAGTF resides within N2/N6E1, Oceanographer of the Navy, U.S. Naval Observatory, Washington D.C. N2/N6E1 reports directly to the Deputy CNO (DCNO) for Information Dominance to enable informed program wholeness and warfighting capability trades for information, cyber, and electronic warfare systems. Led by a two-star admiral, most of the N2/N6E1 staff, to include the admiral, have office spaces at the Pentagon. The N2/N6E1 USMC Requirements Officer represents the Deputy Commandant for Aviation in all aspects of METOC policy and procedures, requirements, acquisitions, and finance and must maintain familiarization with defense acquisition, technology, and logistics life cycle management framework. This officer also monitors Marine Corps METOC programs to ensure requirements are being met and advises the Program Sponsor of program status and milestone accomplishments.

Marine Liaison, Commander Naval Meteorology and Oceanography Command The United States Marine Corps Liaison Officer, Commander Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) resides within N3, and is the principal advisor and subject matter expert for all MAGTF METOC support capabilities. Duties include: assist COMNAVMETOCCOM in aligning the METOC support requirements for littoral and expeditionary warfare operations to include the proper employment and optimal utilization of MAGTF METOC capabilities in support of joint/combined operations; advise and assist COMNAVMETOCCOM in the planning, programming, budgeting, and procurement of MAGTF METOC equipment and in the preparation of concept of operations, specifications, and review of technical data for such equipment; assist in the development and review of METOC training

materials, publications, instructions, and directives in support of MAGTF littoral and expeditionary warfare operations; and serve as direct Liaison between Headquarters, Marine Corps (APX-9), Director of Intelligence (DIRINT), and COMNAVMETOCCOM for all matters requiring the concurrence of the Commandant of the Marine Corps.

Space and Naval Warfare System Command (SPAWAR) The SPAWAR METOC Officer serves as the Aviation Program Manager (APM) for METOC equipment in the Battlespace Awareness and Information Operations Program Office (PMW120) under the Program Executive Office (PEO) Command, Control, Communicate, Computers and Intelligence (C4I). Duties include: ensures that validated Marine Corps METOC requirements are satisfied; provides technical assistance regarding Marine Corps operations to other METOC project officers within and external to the METOC Systems Office; maintain, organize, and disseminate METOC software; and plan and manage the design, development, procurement, and life cycle support of hardware and software systems that measure, transmit, distribute, and process METOC data.

U.S. Marine Corps Forces (MARFOR). The MARFOR METOC officer serves as a Special Staff for the Commanding General of the MARFORs and resides within the G-2. The primary mission of the MARFOR METOC Officer is to advise and assist the MARFOR Commanding General in the development of METOC policies and the execution and management of METOC resources by planning, coordinating, and validating the collection, evaluation, interpretation, and dissemination of METOC data. Other duties include: maintain liaison with other Service counterparts and represent the MARFOR Commanding General at Joint Service METOC meetings; maintain staff cognizance and management coordination for METOC-related matters; serves as the Marine Corps Senior METOC Officer (SMO) when the MARFOR Headquarters (HQ) deploys; conducts staff studies directly related to improving MAGTF Warfighting capabilities; prepare and present staff and command level briefings; provides staff support in planning for the employment and use of organic METOC assets, equipment, and capabilities; provide climatological, meteorological, tidal, astronomical, and other METOC data for planning; and develop and prepare the METOC annex (Annex H) for OPLANs or OPORDs and provides METOC input into the communications and information systems (CIS) annex (Annex K), the intelligence annex (Annex B), and other annexes as necessary regarding METOC issues. MARFOR billets include assignment to Marine Forces Pacific (MARFORPAC) Camp Smith, HI and Marine Forces Command (MARFORCOM) Norfolk, VA.

Marine Expeditionary Force (MEF). The MEF METOC Officer serves as a Special Staff for the Commanding General of the MEF and resides within the G-2. The primary mission of the MEF METOC Officer is to advise and assist the MEF Commanding General in the development of METOC policies and the execution and management of METOC resources by planning, coordinating, and validating the collection, evaluation, interpretation, and dissemination of METOC data. Other duties include: maintain liaison with other Service counterparts and represent the MEF Commanding General at Joint Service METOC meetings; maintain staff cognizance and management coordination for METOC-related matters; serves as the Marine Corps SMO when the MEF HQ deploys; conducts staff studies directly related to improving MAGTF Warfighting capabilities; prepare and present staff and command level briefings; provides staff support in planning for the employment and use of organic METOC assets, equipment, and capabilities; provide climatological, meteorological, tidal, astronomical, and other METOC data for planning; and develop and prepare the METOC annex (Annex H) for

OPLANs or OPORDs and provides METOC's input into the CIS annex (Annex K), the intelligence annex (Annex B), and other annexes, as necessary regarding METOC issues.

Intelligence Battalion (Intel Bn). The Intel Bn provides the largest preponderance of METOC personnel outside of the Aviation Combat Element (ACE) and provides direct and general support METOC personnel in the form of METOC Support Teams (MSTs) to all other elements of the MAGTF. The Intel Bn's primary mission is to provide direct METOC support to the MEF G-2. The secondary mission is to provide MSTs to the Command Element (CE), Ground Combat Element (GCE), Logistics Combat Element (LCE), and Marine Expeditionary Units (MEUs); and are task-organized to support unique mission requirements.

Marine Division (MARDIV). The MARDIV METOC Chief serves as a Special Staff for the Commanding General of the MARDIV and resides within the G-2. The primary mission of the MARDIV METOC Chief is integrate into operational planning. Other duties include: prepare and present METOC briefs in support of mission planning and execution; forecast and identify environmental factors expected to impact operations; and provide expertise METOC input in the areas of Doctrine, Organization, Training, Material, Leadership, Personnel, and Facilities on behalf of the Commanding General of the MARDIV.

Marine Logistics Group (MLG) The MLG METOC Chief serves as a Special Staff for the Commanding General of the MLG and resides within the G-2. The primary mission of the MLG METOC Chief is to integrate into operational planning. Other duties include: prepare and present METOC briefs in support of mission planning and execution; forecast and identify environmental factors expected to impact operations; and provide expertise METOC input in the areas of Doctrine, Organization, Training, Material, Leadership, Personnel, and Facilities on behalf of the Commanding General of the MLG.

Marine Aircraft Wing (MAW). The MAW METOC Officer serves as a Special Staff for the Commanding General of the MAW and resides within the G-2. The primary mission of the MAW METOC Staff is to integrate into operational planning and advise the Commanding General on the capabilities and limitations of the METOC personnel and equipment with the MAW. Other duties include: prepare and present METOC briefs in support of mission planning and execution; forecast and identify environmental factors expected to impact operations; supervise the METOC collection strategy for the Air Wing; man and train TACC METOC personnel; assist subordinate commands in knowledge development for all METOC personnel in the Wing; and provide expertise METOC input in the areas of Doctrine, Organization, Training, Material, Leadership, Personnel, and Facilities on behalf of the Commanding General of the MAW.

Marine Air Control Group (MACG). The MACG METOC Chief serves as a Special Staff for the Commanding Officer of the MACG and resides within the S-3/S-5. The primary mission of the MACG METOC Chief is to integrate into operational planning and to advise the Commanding Officer on the capabilities and limitations of the METOC personnel and equipment within the MACG. Other duties include: assist in the execution and management of all METOC resources; coordinate effective methods of providing METOC support for the planning and execution of MAGTF operations; analyze and interpret centrally prepared products, alphanumeric data, satellite images, and Doppler radar coverage in order to provide forecast meteorological conditions, space weather, climatological and astronomical products, and impacts

assessments for all requested operations within the scope of the MACG and its subordinate commands.

Marine Air Control Squadron (MACS)

MACS Weapons and Tactics Training Program (WTTP) The MACS METOC WTTP Chief is the subject matter expert to the Commanding Officer of the MACS and resides within the WTTP shop. The primary mission of the MACS METOC WTTP Chief is to supervise the training progression of MACS METOC personnel in accordance with MCO 3500.14C Aviation Training and Readiness Program Manual and NAVMC 3500.38A METOC Training and Readiness manual by continuously monitoring and supervising training input into Marine Sierra Hotel Aviation Readiness Program (MSHARP) and all source documentation to accurately portray combat readiness of the METOC sections within the MACS MATCDachments (Dets).

MACS Marine Air Traffic Control Detachments (MATCD) The MACS MATCD are where the preponderance of METOC personnel resides within the MAW. They also own and maintain the largest METOC support asset within the MAGTF; the Meteorological Mobile Facility (Replacement) Next Generation [METMF(R) NEXGEN]. The METMF(R) NEXGEN is deployed to support sustained operations ashore and provides METOC personnel with a forward deployed data collection asset that is comparable to garrison systems. MACS MATCD METOC personnel provide general support to the Aviation Combat Element (ACE), but can be task-organized by way of METOC Support Teams (MSTs) to support the other elements of the MAGTF when requested through the chain of command. The duties of the MACS MATCD METOC personnel include: acquire, monitor, and analyze METOC data to produce tailored, value added information for supported units; operate all METOC equipment, including satellite receivers, radar, and other available environmental sensors and display equipment used as the basis for collecting and forecasting environmental conditions; prepare and disseminate forecasts focused on specific missions, locations, and METOC parameters critical to current operations and future planning; forecast upper-level winds; provide aviation flight weather briefings in support of aviation missions; and provide WWAs in support of sustained operations ashore to ensure force protection.

Operational Supporting Establishments

Regional METOC Center (RMC). The Marine Corps' RMCs provide 24 hour direct (in person) and indirect (web, e-mail, and phone) regionalized METOC information, products, and services in support of Marine Corps operations and other military operations as may be directed from a garrison environment. The RMCs may be used as a reach-back source, but are not task-organized to provide operational METOC support to forward deployed personnel or to act as METOC Production Centers for other-than-garrison operations. RMCs have the secondary mission to coordinate and supervise the training of all METOC forecasters in the MCICOM chain of command. As part of the regionalization concept of the RMCs, they are responsible for 24/7 METOC support for the station they are aboard and after field closure for all other stations within their area of responsibility (AOR). Those duties include: collect, evaluate, interpret, and disseminate METOC observations and forecasts; prepare and disseminate WWAs; prepare and brief aviation flight weather briefs; forecast upper-level winds; prepare and disseminate yearly

astronomical data; provide climatological data upon request; and complete all other METOC request for information (RFI) as requested.

Other CONUS Marine Corps Bases and Air Stations. Station METOC support responsibilities include: METOC support to base training, tenant units, and transient aircrews; and liaison with the RMC to provide a continuous meteorological watch (METWATCH). The RMCs have final issuing authority for all terminal aerodrome forecasts (TAF) and weather WWAs for the bases and air stations within their respective area of responsibility. Other duties include collect, evaluate, interpret, and disseminate METOC observations; prepare and brief aviation flight weather briefs; forecast upper-level winds; prepare and disseminate yearly astronomical data; provide climatological data upon request; and complete all other METOC RFIs as requested. Although collaboration between the Station METOC subject matter expert and RMC personnel occurs, the RMCs have final issuing authority for all terminal aerodrome forecasts (TAF) and WWAs for the stations and bases within their respective region.

Marine Corps Aviation Support. The Marine Aircraft Wing (MAW) conducts 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.

Marine Corps Products and Services

METOC Support Capabilities—Meteorological Mobile Facility (Replacement) Next Generation [METMF(R)NEXGEN]. The highest level of METOC capability within the MAGTF is the METMF(R) NEXGEN. The METMF(R) NEXGEN provides the MAGTF with a lightweight, highly mobile, fully integrated FORCENet compliant meteorological system capable of sustaining METOC operations in direct or general support of all elements of the MAGTF. It provides a METOC capability similar to that found in garrison METOC facilities. METMF(R) NEXGEN provisions for all functions of environmental sensing and data ingest, for the efficient collation and integration of collected data, and for user-friendly graphic user interfaces (GUIs) and software tools necessary for accurate interpretation and value-added production. The METMF(R) NEXGEN enables the Marine METOC personnel to effectively turn relevant METOC data into actionable environmental information which in turn can facilitate timely operational decision-making. The

Figure 10: Meteorological Mobile Facility (Replacement) Next Generation [METMF(R)NEXGEN] deployed to Afghanistan

smallest level of METOC capability is the Naval

Integrated Tactical Environmental System - Variant IV (NITES IV). The NITES IV is designed as a scalable, flexible, and mobile system for a first in and last out capability. The primary differences between the METMF(R) NEXGEN and NITES IV are size, logistics, scalability, mobility, and that the METMF(R) NEXGEN has organic sensing capabilities while the NITES IV sensing capabilities are limited. Thus, the NITES IV relies heavily on reach-back communications and MFC databases for data and products. The NITES IV provides METOC personnel access to METOC data and products which are then analyzed and tailored for a specific mission.

Naval Integrated Tactical Environmental System (NITES IV). 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. Mission requirements, network availability, and embarkation space dictate how best to employ NITES IV.

Vaisala TacMet Meteorological Observation System. Organic to the METMF(R) NEXGEN and NITES IV, the TacMet is a field deployable, compact weather station for various field operations. Offering broad sensor capability, the local MAWS201M network system is used to provide weather data to support air operations on a temporary or semi-permanent basis. The local system enhanced configuration offers full aviation support, interfacing with intelligent sensors such as ceilometer, present weather sensor, and electric field mill. These sensors are capable of being deployed up to 150 feet away from the systems. A standalone version of this sensor is also available to the METMF(R) NEXGEN in the form of two (2) Remote Sensor Sub-systems (RSS). The RSS includes meteorological sensors from pre-positioned, remote locations. This portable, scalable system comprises a sensor set with wind speed and direction, barometric pressure, air temperature, relative humidity, and precipitation sensors.

Figure 11: METMF(R) NEXGEN provides critical enabling capabilities to collect, process, disseminate and integrate essential elements of information regarding the time-sensitive characterization of the physical environment. Official U.S.M.C. photograph.

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

Interagency Supporting Research Programs and Projects

National Unified Operational Prediction Capability Research Partnering Initiative

This initiative is a Navy, Air Force, and NOAA/NWS tri-agency management organization focused on coordinating development and transition to operations of numerical weather technology advances to improve joint mission performance. 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 five 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 effort partners with the Earth System Predictions Capability (ESPC) to improve and extend forecast skill through coupled systems. This effort is research focused to stimulate inter-agency interactions and collaborations in developing systems to improve forecasts at time scales from near-term weather to inter-seasonal/inter-annual. It also is working to couple domains such as atmosphere, ocean, ice, land and eventually into ecosystems. Improvements in predictions in these broader domains and timescales 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 will work to operationalize findings from ESPC for the next generation environmental prediction system. More information is available at the NUOPC website at: www.weather.gov/nuopc/ and the ESPC website at: www.espc.oar.noaa.gov/.

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. USAF capability needs in the atmospheric and space environment sciences are articulated in the Initial Capabilities Document for the METOC Environment, Capability Review assessments, USAF Strategic Plans, the AF Weather Operations Functional Concept and Enabling Concepts (Characterize the Environment, Exploit Environmental Information, and Net-Centric Operations), and supporting concept and

implementation plans. The USAF 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 AF weather enterprise. 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. AF weather 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 Air Force is transitioning to a global forecasting capability with the implementation of their Global Air-Land Weather Exploitation Model (GALWEM). Additionally, the USAF will continue participation in research and development activities that bring advanced forecast capabilities in support of USAF and US Army operations 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. The GALWEM is a fully coupled model which brings dust and aerosol modeling capabilities. The Land Information System analyzes the current state of the land surface to provide information to DoD and civilian agencies, and, through coupling with GALWEM, will improve forecasting performance near the surface and in the low levels of the atmosphere. This enables USAF weather 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, the USAF released 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 quantifies biases, allowing concise, focused products.

Research Partnering Initiatives. The USAF is partnering with the NWS and the Navy in the National Earth System Prediction Capability (N'ESPC). This partnership exists to enable a tri-agency joint global atmospheric ensemble forecast system and is an integration of ongoing efforts coordinated by a tri-agency management organization. The N'ESPC 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. The USAF 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. 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 conducts basic and applied research in atmospheric science and technology 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 of aerosols, acoustics, electro-optics, and adaptive optics to support advances in detection and identification within the battlefield environment; (2) research to understand, measure, model, and predict, the dynamics of the boundary layer atmosphere and its effects on Army systems and operations; and (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. This mission effort will be carried out through the: (1) development of high-resolution, physics-based and semi-empirical models for urban and complex-terrain meteorology; (2) development of Decision Support Tools (DSTs) that describe the impacts expected, and the resulting performance degradation due to adverse environmental conditions, to include weather and terrain, for both Friendly and Threat systems; and (3) development of improved propagation and scattering models to be employed in novel techniques that can enhance the detection, identification, and localization of biological aerosols and acoustic and optical sources, and to enable evaluations that will improve the performance of acoustic and electro-optic sensors. ARL also provides a liaison to the Joint Polar Satellite System Program Office located at the NASA Goddard Space Flight Center to coordinate on Army satellite data, information requirements, and applications development. The following three research programs are planned within ARL-BED for FY16.

Figure 12: High-resolution meteorological forecasts support a host of battlefield operations such as first round, fire-for-effect artillery shots. (U.S. Army photo)

Atmospheric Sensing. The objectives of this research program include: (1) experimental and theoretical research enabling high-resolution characterization of atmospheric and other environmental conditions that may affect the performance of acoustic and electro-optic systems, and the conception of methods to mitigate these effects; (2) development of aerosol, acoustic, and electro-optic DSTs that utilize observed or modeled atmospheric parameters to improve Warfighter performance within the battlefield environment; (3) development of theoretical and experimental technologies for the characterization of atmospheric constituents focused on the detection of threat agent aerosols; and (4) development and advancement of environmental remote sensing science and technologies to increase knowledge of the battlefield environment and to support Army operations. ARL also provides a liaison to the NOAA Joint Polar Satellite System Program Office located in Lanham, MD to coordinate on Army satellite data, information requirements, and applications development.

Atmospheric Modeling. The objectives of this program are to: (1) develop high-resolution, physics-based prognostic models and semi-empirical diagnostic models for ultra-fine-scale meteorological forecasts in urban and complex terrain; (2) develop, modify, or adapt data assimilation tools that can ingest on-scene, traditional, and non-traditional weather observations, and fuse this information with forecasts to provide analyses and mission-execution Nowcast products for operations and short-term mission planning; (3) design and develop the means to

process these models and transfer meteorological data over a distributed network; (4) develop capabilities to use deterministic and ensemble model probabilistic forecast output in weather DSTs, and develop new aids to exploit such new databases; and (5) support the Artillery Meteorology community with expertise in meteorological modeling and atmospheric effects on artillery fires and target area meteorology.

Atmospheric Dynamics. The objectives of this effort are to: (1) develop applications to monitor and assess airborne hazards in complex terrain; (2) develop theoretical foundations and perform experiments to characterize the fine-scale effects of local terrain on winds, turbulence, and vertical fluxes; (3) develop DSTs and associated databases that describe the impacts expected, and the resulting performance degradation due to adverse weather conditions for both Friendly and Threat systems; (4) assess the accuracy and value-added to the Warfighter of Nowcasts and DSTs; and (5) develop propagation models and improved theory for characterizing the atmosphere and the effects of turbulence on emerging sensing applications in previously under-exploited spectral regions (including Terahertz) for communications and imaging, short-wave infrared active and passive imaging, and near-IR for directed energy systems. As part of the Atmospheric Dynamics research efforts, and in support of the modeling and sensing areas, ARL will be implementing a Meteorological Sensor Array (MSA) within and near White Sands Missile Range, NM (WSMR) in late FY15 and extending to maturation in FY16. The MSA will consist of two, thirty-six meteorological tower sensor arrays; with other associated instrumentation such as LiDARs, SODARs, etc., situated in complex mountain/desert terrain. This test bed will provide a rich source of atmospheric characterization data for ARL and other research organizations.

ARL Army Research Office. The Army Research Office, Research Triangle Park, North Carolina, manages the Army's extramural basic research program in earth sciences. ARO seeks to advance understanding of the terrestrial environment by embracing long-term, high risk, high-payoff opportunities for the US Army with special emphasis on Earth Materials and Processes and Environmental Chemistry. Research seeks to explore the properties of Earth surface materials and environments to discover how they respond to external forces and their interactions with the atmosphere, hydrosphere, and biosphere, especially in the context of chemical species affecting human health and the environment. The work is focused on processes occurring at spatial and temporal scales relevant to Army operations and land management. Fundamental research lays the foundation to support a range of Army needs, including the remote characterization of land surfaces, the trafficability of ground vehicles, and environmental needs such as waste management and remediation.

U.S. Army Corps of Engineers R&D

The U.S. Army Corps of Engineers' (USACE) Engineer Research and Development Center (ERDC) provides integrated research, development, and engineering services to solve the challenging problems in military engineering, geospatial sciences, water resources, and environmental sciences for the Army and Department of Defense (DoD). The ERDC supports Army weapon systems RDT&E with all-season solutions for mitigating adverse environmental effects on Army operations. Basic and applied research is conducted on energy and mass transfer processes at and near the terrain surface. ERDC develops databases and models for predicting the state of the terrain including surface temperature, soil moisture, tactical decision aids, and

geospatial tools supporting mobility analysis and sensor performance. Research will transition into Tactical Decision Aids (TDAs) within geospatial analysis tools to interpret and assist the Warfighter's understanding of weather impacts on terrain applicable to Mission Command and Intelligence, Surveillance and Reconnaissance planning. These products transition to research and engineering programs including advanced technology demonstrations and specific programs of record.

FY16 planned efforts include research supporting the Army Terrestrial Modeling and Intelligence System (ARTEMIS) Army Science and Technology Objective (STO). This Army STO is being executed in partnership with the Army Research Laboratory's Battlefield Environment Division. FY16 planned efforts include: (1) the development of digital product layers that reflect land-atmosphere impacts on mobility, austere entry, and sensor performance and research risk-based analysis of terrestrial processes on military operations; (2) conducting research of time-sensitive activity within the soil as shaped by dynamic soil descriptors to support enhanced predictive analysis of soil-weather-terrain governed maneuver and sensor constraints; and (3) the investigation of remote and automated analysis methods for identifying and locating areas suitable for aircraft landing or drop zones

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 seven ATEC ranges.

Enhancements to ATEC Four-Dimensional Weather System. The ATEC Meteorology Program is continuing to collaborate with the National Center for Atmospheric Research (NCAR) on enhancements to the ATEC Four-Dimensional Weather (4DWX) system, which is the backbone of the meteorological support infrastructure at the Army test ranges. ATEC 4DWX modeling capabilities include Weather Research and Forecasting (WRF) model based real-time four-dimensional data assimilation at the test ranges. It also provides 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.

In 2007, DPG implemented a 30-member ensemble 4DWX forecasting capability. Recently, the High Performance Computing Modernization Office (HPCMO) provided ATEC an allocation of hours in a high-priority queue at the Navy DoD Supercomputing Research Center at Stennis

Space Center, for development of an extension of the ensemble 4DWX to all the ATEC test ranges.

System enhancements during FY15 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; improved lightning potential prediction; development of range climatologies; continued development of Very Large Eddy Simulation capabilities; continued development of an on-line automated real-time quality control for observations; and continued enhancements to the AutoNowcaster implementations at Redstone Test Center and at White Sands Missile Range. In addition, preparations are underway to install a weather surveillance radar at the Cold Regions Test Center, Fort Greely, Alaska. ATEC plans to evaluate an upgraded sound propagation model under development at the Naval Surface Warfare Center, Dahlgren, Virginia, for potential use at Aberdeen Proving Ground, Maryland.

U.S. Navy Supporting Research Programs and Projects

Earth System Prediction Capabilities. Navy's Earth System Prediction Capability (ESPC) project was established in FY 2013 to address Fleet and Combatant Commander (COCOM) METOC prediction requirements and capability gaps. Navy ESPC is part of a larger National operational, coupled numerical model development and model ensemble collaboration across DoD and other Federal Agencies. Initial Operational Capability (IOC), defined as a fully coupled global 16-day prediction system and prototype/demonstration capability to predict inter-seasonal variability (< 90 days), is scheduled for FY 2018. Full operational capability, consisting of a 32-day coupled global ensemble, coupled regional Arctic and inter-seasonal to inter-annual variability prediction capability, is scheduled for FY 2022.

The ESPC primary deliverable is a multi-model global ensemble forecast system, coupling the domains of land, sea, atmosphere, ice, and space. Improvements in predictive capability are expected to result in better severe weather warnings (hurricanes, tornadoes, snowstorms), better cost avoidance for weather sensitive industries (agriculture, transportation, utilities, defense), and better informed decision making for industry, defense, and the general public. Additional information is available at the ESPC website at: www.espc.oar.noaa.gov/

Electromagnetic Maneuver Warfare (EMW) Under the mission pillar of Assured Command and Control, in direct support to EMW, the Navy is engaged in improving Electro-Magnetic (EM)/Electro-Optic (EO)/Electronic Warfare (EW) Spectrum Management, especially in Anti-Access/Area-Denial (A2/AD) environments by improving exploitation opportunities across current and emerging fleet sensor systems. The NOe under COMNAVOCEANCOM direction, has partnered with Program Manager Ships (PMS 405) in coordinating atmospheric and oceanographic efforts for Solid State Laser (SSL) Technology Maturation (TM) and Quick Reaction Capability (QRC). An Integrated Product Team (IPT) is charged with providing 24/7 atmospheric characterization and performance prediction for SSL operations at any maritime location of Navy interest. Current focus is on modeling and measurements, needed in developing vertical temperature/moisture and turbulence profiles. CNMOC is the Navy authoritative source for what atmospheric models to tap into and FNMOC is the Navy's lead atmospheric modeling center. Other participants include ONR 34, NRL, and COMNAVSPAWARSYSCOM. Tech Solutions is a SPAWAR-led R&D effort for a weather sensing system onboard naval surface ships called Automated Shipboard Weather Observation System (ASO). The design of a variety

of laser systems, for example, the Modular Universal Laser Equipment (MULE), has used the R&D turbulence models to optimize systems for operation in the atmospheric environment expected in different operational theaters.

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, space systems, Earth's atmosphere, and the space environment. Space weather services include monitoring and alerting of space weather storms and their effects on technological infrastructure and human safety. 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. 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. SWPC operates the national civilian Space Weather Forecast Office, coordinating with Air Force's 557th Weather Wing 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 products and services include observations and forecasts of solar, interplanetary, geospace, ionosphere and thermosphere conditions that impact technologies on Earth and in space. The SWPC also develops and

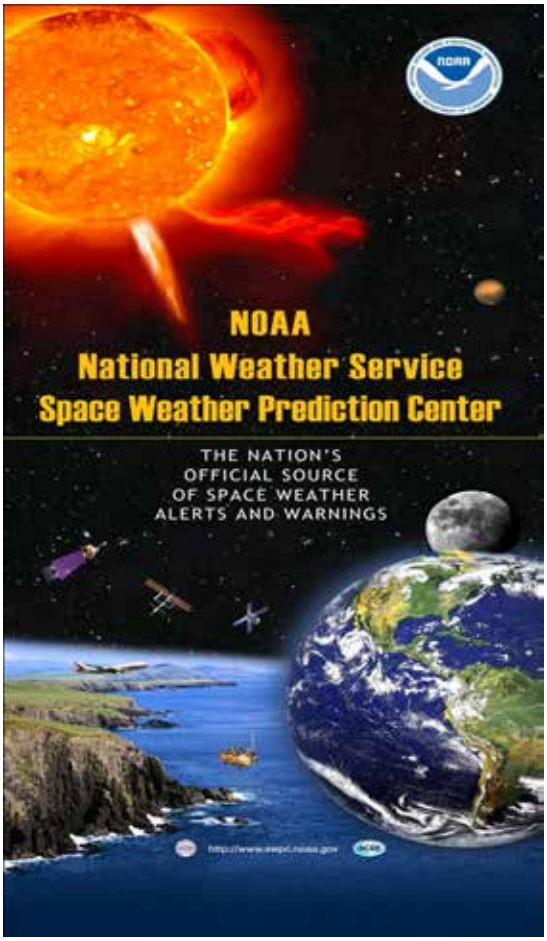


Figure 1: Space Weather Prediction Center illustration.

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 Department of Defense, National Aeronautics and Space Administration, Department of Homeland Security, Department of Energy, and Department of Transportation. 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 high frequency communication and satellite navigation. The SWPC also serves as the primary international World Warning Agency for the International Space Environment Service. 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 AF weather organizations is to enable DoD decision-makers to anticipate and exploit the weather for air, ground, space, cyberspace, and intelligence operations. As this applies to the 'Space Weather Services' category, AF weather personnel provide space environmental information, products, and services required to support Department of Defense (DoD) operations as required, providing actionable environmental impacts information directly to decision makers.

The USAF's Space Weather Flight is the Department of Defense'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), 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.

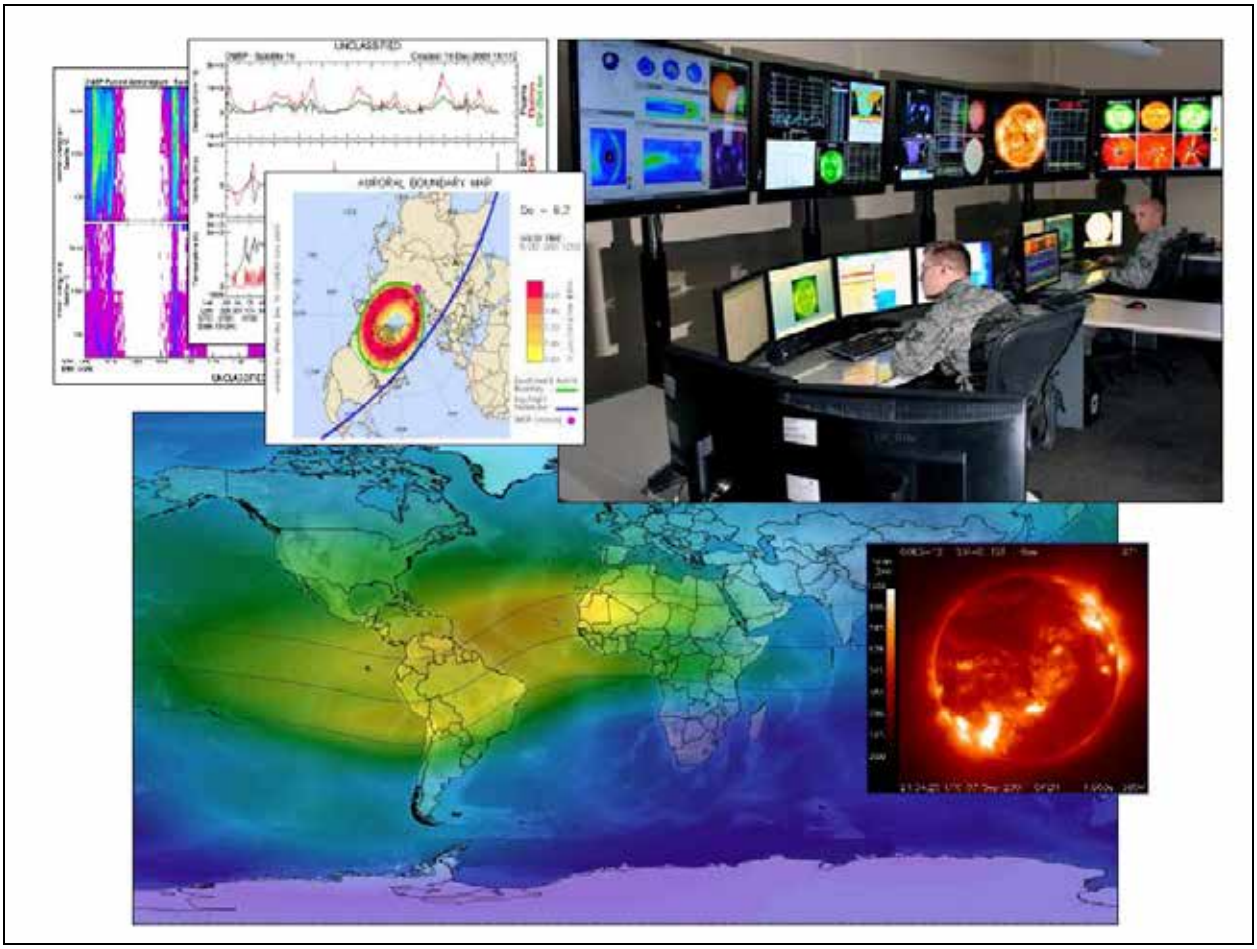


Figure 2: 2nd Weather Squadron's Space Weather Flight monitors solar emissions 24/7 and provides mission-tailored analysis, forecasts and warnings.

The 2 WS also provides immediate backup support for the SWPC. The backup includes the use of on-site Air Force personnel at the 2 WS. The 2 WS space weather technicians located at Offutt Air Force Base (AFB), Nebraska, and at solar observatories around the globe are always focused on the sun. They provide timely, relevant, and accurate space weather information to DoD personnel, issuing approximately 35,000 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, e.g. ionosphere, ground-based and space-based systems complement each other to provide highly accurate point source verification and specification as well as 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 provide information (or data) unobtainable from the ground. Space-based systems provide in situ measurements of the space environment; i.e., solar wind and magnetosphere. The USAF has outlined plans to modernize ground-based space environment sensing and is collaborating with U.S. and Allied government and civilian agencies to achieve a robust space-sensing capability.

The 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
- Detachment 5, Kaena Point, Hawaii
- San Vito, Italy (contract site)

The SEON network sites utilize the Radio Solar Telescope Network (RSTN) and/or the Solar Observing Optical Network (SOON). The RSTN is composed of instruments that observe radio emissions from the sun and is used to monitor for solar radio bursts at eight specific frequencies as well as a spectral band. The SOON is used to monitor solar flare activity, which are sometimes the precursor to 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 (white light), which shows sunspots on the sun's surface, or photosphere. The SOON also enables the production of magnetic maps of the sun using a Zeeman splitting technique. 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.

The USAF employs a worldwide network of ground-based ionosondes and other sensors to provide environmental data in the ionosphere. It manages the NEXt-generation IONosonde (NEXION) fielding that started in summer of 2009, which will culminate in 26 NEXION sites worldwide. The USAF is in the process of fielding a network of 10 Ionospheric Scintillation and Total Electron Content (TEC) Observatories (ISTO), expected to be operational in 2016. These sites will characterize attenuation of SATCOM and GPS radio signals in the global equatorial regions. NASA's Jet Propulsion Laboratory operates a complementary global network of more than 125 sensors, deriving ionospheric line-of-sight total electron content from GPS signals, and provides these data to the USAF. Additional data are provided by the U.S. Geological Survey (USGS), which

Figure 3: Solar optical and radio telescopes at Learmonth, Australia. Source: U.S. Air Force.

operates a network of ground-based magnetometers, primarily in North America, that provide the USAF with critical measurements of the earth's geomagnetic field and its variances.

From space, the Defense Meteorological Satellite Program (DMSP) Special Sensor Precipitating Electron and Ion Spectrometer measures low-energy precipitating electrons that cause the aurora. The DMSP Special Sensors-Ions, Electrons, and Scintillation sensor provides top-side, in-situ 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-15 satellite monitors solar X-ray emissions and provides near real-time display at 557 WW and the SWPC in Boulder, Colorado. The USAF also leverages space-based data from NASA and other agencies.

AF weather organizations will continue to lead the Department of Defense in space weather operations in FY 2016 and beyond. In FY 2016, the USAF will continue 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. The Geomagnetism Program monitors ground-level magnetic activity by operating 14 magnetic observatories in the United States and its territories. Data from these observatories are transmitted to the Program's headquarters in Golden, CO in near-real time. USGS and foreign observatory data streams are used to calculate storm-time disturbance indices, such as the magnetospheric ring-current index Dst, which serves as a standard proxy measure of magnetic storm intensity and is an important input to numerous operational physics-based models of the magnetospheric-ionospheric system. Data and storm-time disturbance indices are transmitted to SWPC, U.S. Air Force, and NASA in real time. In addition, USGS data are utilized by private industry, foreign space weather agencies, and academia.

USGS observatories are operated in cooperation with INTERMAGNET (http://www.intermagnet.org), an international consortium that coordinates the operation of over 120 geomagnetic observatories in 40 different countries; the role of INTERMAGNET was recently summarized in an article in the *EOS* newsletter, which is published by the American

Geophysical Union. The U.S. Geological Survey recently began a novel public-private cooperative relationship with the oil and gas drilling industry to operate a magnetic observatory in Alaska. 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 participated in the development of the National Space Weather Strategy (NSWS) and it's supporting Space Weather Action Plan (SWAP). Specifically, FEMA took the lead in developing Goal #2: Enhance Response and Recovery Capabilities alongside partner agencies including: DOE, DHS, NOAA and others. Additionally, FEMA participated in the development of the remaining goals. FEMA will continue to coordinate with NOAA-SWPC, NASA, DHS and other agencies to better understand the forecasting, observation, and impact analysis of space weather events.

FEMA continues to work across the Federal interagency to develop partnerships to increase preparedness against space weather threats. Along with the Department of Energy, FEMA has led the development of the Power Outage Incident Annex (POIA) to the Response and Recovery Federal Interagency Operations Plans (FIOP) to prepare for one of the primary threats from an extreme space weather event. While still under development, this plan will address the Federal government's roles and responsibilities during a large-scale, widespread power outage. In addition, to increase awareness of space weather across the Whole Community, FEMA maintains a space weather section on the Ready.gov website (http://www.ready.gov/space-weather).

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 provides research and development support for SWPC including model development and transition. The SWPT also validates and verifies new research results from the broader research community and works to develop and transition research models into operational products and services. Through these activities the SWPT achieves its principal objective of infusing the benefits of new research and technology 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 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 implementing a geospace/magnetosphere model so that SWPC can provide customers with regional forecasts and specifications of space weather impacts on Earth.
- Improving estimates of auroral impacts by the development and transition of a three -day 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 Global Positioning System /Global Navigation Satellite System (GPS/GNSS) customers by the development of the Integrated Dynamics of Earth's Atmosphere (IDEA) model which combines the Whole Atmosphere Model (extended NWS/GFS model) and the Ionosphere Plasmasphere Electrodynmics model. This coupled modeling systems will provided multi-day forecasts of the conditions that lead to ionospheric scintillation and the disruption of the GPS and GNSS signals.

U.S. Air Force

Air Force Research Laboratory

The Air Force Research Laboratory (AFRL) supports the Air Force 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 including 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.

U.S. Geological Survey

The USGS Geomagnetism Program pursues scientific research for purposes of fundamental understanding of geomagnetic hazards, and developing products and services needed for related hazard assessment and monitoring. This work is consistent with priorities established in the strategic plans of the USGS Natural Hazards Mission Area (Goals 2 and 4, 2012), the National Space Weather Program (NSWP, Goals I and III, 2010), the Subcommittee for Disaster Reduction (SDR, Grand Challenges 1 and 2, 2010), and the Space Weather, Operations, Response, and Mitigation project of the National Science and Technology Council (SWORM, NSTC, Goals 1 and 5, 2015).

USGS Geomagnetism Program research contributes to the broad understanding of the Earth and its surrounding geospace. At the same time, Program research is targeted for societal relevance, especially for ground-level hazards associated with variable space-weather conditions. Program scientists analyze geomagnetic data, often in conjunction with other types of data, such as solar-wind data collected by satellites or geoelectric data collected during magnetotelluric surveys. Some Program research projects are phenomenological and inferential in nature, involving statistical and time-series analysis methods. Other projects involve comparisons of geomagnetic data and physics-based deterministic models. Specific projects include analysis of extreme magnetic-storm events, estimation of lithospheric and deep-Earth electrical conductivity, induction of geoelectric fields in complex lithospheric conductivity, and magnetospheric-ionospheric model prediction of ground-level geomagnetic disturbance.

Program research leads to the development of products and services needed for assessments and real-time situational awareness of geomagnetic hazards, and it informs the operation of the observatory network. Specific development work includes calculation of magnetic activity indices and mapping of geomagnetic disturbance. Work in support of operations includes the evaluation of data quality, averaging, and bias. Program research staff provide expert scientific advice, national and international leadership, and write research and educational articles about geomagnetism and associated hazards.

National Aeronautics and Space Administration

The objective of the Heliophysics Division of the National Aeronautics and Space Administration's (NASA) Science Mission Directorate (SMD) is to understand the Sun and its interactions with Earth and the solar system, including space weather. 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 19 missions involving 33 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.

To meet national and societal needs, NASA coordinates its space weather activities with several interagency and international partners, including the National Oceanic and Atmospheric Administration (NOAA), which is responsible for delivering operational space weather products and services to the nation. Currently, five 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. Additional space weather information is provided by the two Solar Terrestrial Relations Observatory (STEREO) spacecraft which broadcast beacon images of the far side of the Sun; as well as coronal mass ejection alerts from the European Space Agency (ESA)/NASA Solar and Heliospheric Observatory (SOHO) and super high-resolution images from the Solar Dynamics Observatory (SDO). Also, the two Van Allen Probes provide near-real-time information on the conditions in the Earth's radiation belts.

NASA also supports the development of space weather technology and predictive capability 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 that enables 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 National Science Foundation (NSF), NOAA, and the DoD.

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. Space Weather is now a dedicated program at NSF, and is joined by several cross-cutting programs (CEDAR/GEM/SHINE) and support for NCAR's High Altitude Observatory. 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.

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 (NWS)

National Weather Service's (NWS) Marine Program is the lead for the Nation's marine and coastal weather services, encompassing a vast area from 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 ensuring safe and efficient transportation, fishing, recreation and offshore mineral exploration, 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), the National Hurricane Center (NHC) and the Ocean Prediction Center (OPC) 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 and high seas waters, and Great Lakes near-shore and open lake waters. Coastal WFOs have responsibility for forecasts and warnings extending up to 60 nautical miles from the shore. NHC and OPC are responsible for offshore and high seas waters, meeting U.S. obligations to maritime weather safety under the International Convention for Safety of Life at Sea, to which the United States is a signatory.

Using observational data sources such as buoys and satellites, and numerical model guidance, NWS forecasters monitor weather conditions continuously over their responsible maritime domain. They produce and disseminate routine forecast products and analyses, watches, warnings, and advisories which describe maritime weather, sea ice and oceanographic conditions including tropical storms and coastal storm hazards. NWS coastal marine warning and forecast products describe wind, waves, visibility, icing, storm surge, coastal flooding, severe weather, high surf and rip currents. NWS tropical storm products describe track and intensity as well as associated coastal hazards such as storm surge, waves, and inland impacts.

The Marine Program collaborates with a wide range of partners within and outside of NOAA. The program relies on the NWS Office of Observations and NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) for the collection of marine and coastal

observations and the delivery of marine and coastal products to users. Through the joint National Ice Center, the Program collaborates with NESDIS, the U.S. Navy, and the U.S. Coast Guard (USCG) to provide ice warning and advisory services. It supports the U.S. Navy, the U.S. Coast Guard, 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 Department of Defense, Federal Emergency Management Agency (FEMA), Department of Homeland Security (DHS), and USACE to provide tropical cyclone warning and forecast services; with the USCG, U.S. Navy, Air Force, and private entities to disseminate weather information to mariners. It supports NOAA's National Ocean Service (NOS) on the Physical Oceanographic Real-Time System (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 that cover world oceans. It also collaborates with NOAA's Office of Response and Restoration, DOD, USCG and DHS to support emergency responses to maritime incidences such as hazardous material spills; maritime domain search, rescue, and recovery operations; and to maintain maritime domain situational awareness.

The NWS and Federal Highway Administration are working together to improve the incorporation of weather information by state Departments of Transportation (DOTs) in their decision making for high impact weather events. Currently, the NWS provides weather information through a variety of dissemination mechanisms used by some state DOTs for the purpose of ensuring motorist safety, and for protecting life and property. This includes coordination on forecasts and wording of variable message signs along roadways, engagement with state DOTs on 2-way NWSChat and evaluation of road models based on NWS grids. NWS provides direct decision support to some state DOTs in certain non-routine situations, from real-time to seasonal events, which threaten public safety or can cripple road and bridge infrastructure. Support has been provided outside of standard products for fires (particulates and winds), dense fog, dust storms, hazardous material incidents/spills, coastal and inland flooding (flash flood, probabilistic river forecasts, precipitation frequency Atlas and runoff), and dangerous winter conditions (black ice, snow accumulation, melt related flooding) or tropical storms. Direct support includes single-slide Impact-based Decision Support Services graphics prepared for specific DOTs and experimental local graphical travel pages. State DOTs have also captured NWS graphics for redisplay directly on their public websites or internal web pages for each mile marker as well as for content in their 5-1-1 Travel Information Systems. To improve readiness, NWS provides seasonal training workshops and site visits with state departments of transportation.

NOAA/National Ocean Service

Marine Transportation System Services

The National Ocean Service (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 (http://tidesandcurrents.noaa.gov/), 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. These stations were installed as a result of a partnership between NOS and the NWS. Data from these new stations will be used for storm surge & meteorological applications, and to assist emergency managers with real-time data for accurate lake modeling, storm surge predictions, and emergency planning and evacuation orders.

Figure 1: This image is a re-established meteorological station at Frenier Landing, 5 miles from the new water level station Floodway.

Figure 2: This image is a new water level station installed on the western side of Lake Pontchartrain, LA at I-10 Bonnet Carre Floodway.

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. For more information see http://tidesandcurrents.noaa.gov/nwlon.html.

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, waves, bridge air gap and many meteorological parameters, needed and requested by the mariner to navigate safely. There are 25 existing PORTS® systems that comprise a total of 88 PORTS® water level stations. Currently, 72 of these stations contain at least one meteorological sensor (anemometer, barometer, air temperature sensor or a visibility

sensor). In FY15, two new PORTS® were added to the network in Morgan City, and Port Fourchon, LA. In FY16, two new PORTS® are planned in Matagorda, TX and Savannah, GA.

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 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.

Figure 3: Visibility Station in the New Jacksonville PORTS.

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 the Coast Guard's Automated Identification System AIS, 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®, three in the San Francisco PORTS® and three in the new Jacksonville PORTS®. More visibility installations are planned for Narragansett Bay and Chesapeake Bay PORTS® in FY15/16. For more information see http://tidesandcurrents.noaa.gov/ports.html.

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 FY15 modelers worked on updating model engines, making sure the models are running on the latest version. In FY16 NOS hopes to upgrade a model on Lake Erie. 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. Developed in FY13, model information is now

automatically formatted into SHEF bulletin format for inclusion into the NOAA AWIPS system. For more information see http://tidesandcurrents.noaa.gov/nocmp.html.

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.

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, http://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

DOT/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 highways 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).

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 FY2015─ FY2016, 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 Weather Data Environment (WxDE)

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.

From 2006-2013, a U.S. DOT-sponsored experimental system entitled *Clarus* collected, formatted, quality checked, and displayed ESS road weather data from across North America. Upon meeting its goals, the *Clarus* System was decommissioned on June 15, 2013. However, the operational capability of the *Clarus* System is currently being transitioned 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 FY 2015, these agencies have been continuing to collaborate in the transition efforts. An

important area of current research for both agencies is the gathering of weather and road data from vehicles.

Recognizing the continued need for road weather observations in order to execute the RWMP research, the Program started a new project in FY 2014 called the Weather Data Environment (WxDE). The WxDE builds on the *Clarus* system's ability to assimilate and provide access to road weather data from a network of fixed stations across the nation, and perform road weather data quality checks. In particular, the WxDE will support the intelligent aggregation, normalization, warehousing, processing, and dissemination of road weather data gathered from a variety of fixed and mobile sources. In fall 2013, an interim demonstration instance (see image to the right, source: http://www.its-wxde.net/summaryMap.jsp) of the WxDE was launched to the community and since then, numerous improvements have been added to the system. In FY 2015 the program will continue to add improvements to the WxDE and when ready will transition to an operational production instance for general access. The WxDE provides data on an interoperable platform to meet the needs of weather-related research focused towards Intelligent Transportation Systems (ITS). The WxDE will incorporate the most recent version of Vehicle Data Translator 4.1 (VDT – *see next page*) so that input files containing weather data for mobile and RWIS sources, road segment definitions, and contextual data (e.g., radar, RTMA, METAR) can be included in the system. With the VDT 4.1, the WxDE can compute value-added forms of collected data and preform quality checks on mobile data, therefore increasing the amount of weather-related data available.

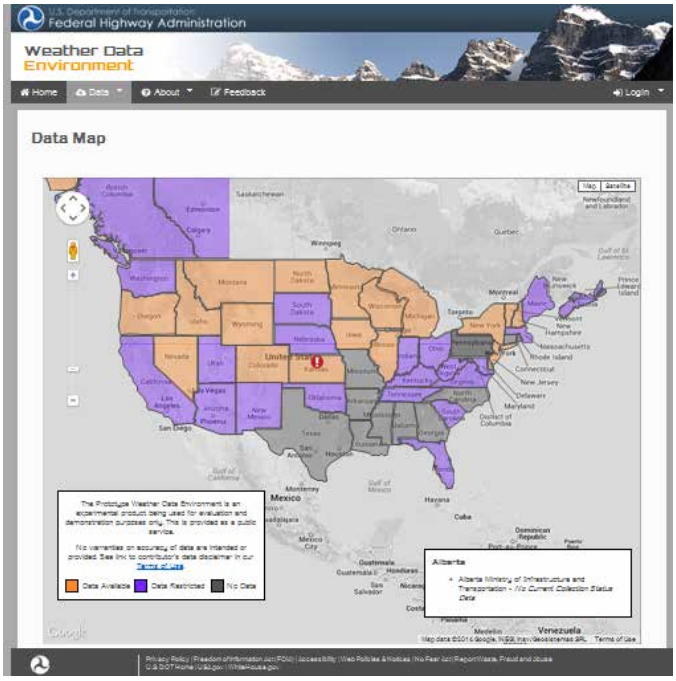


Figure 4: In fall 2013, an interim demonstration instance of the WxDE was launched to the community. Figure 4 is an example of this program.

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.

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

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 partnered with National Center for Atmospheric Research (NCAR) to develop the Vehicle Data Translator (VDT), which processes 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 FY 2014 the VDT was updated from version 3.0 to the Pikalert Vehicle Data Translator (VDT Pikalert). In FY 2015 the Pikalert VDT will receive improvements to the science of its algorithms (for nowcasts, forecasts, analysis, etc.) resulting in VDT version 4.1. The outputs of VDT 4.1, which processes data from connected vehicles and roadside units into meaningful, actionable information, will be used by existing road weather connected vehicle applications. This data set will potentially lead to the development of new road weather connected vehicle applications as well. The VDT is made available to application developers and others via the Open Source Application Development Portal (OSADP) - http://itsforge.net/.

In FY 2015 the FHWA will continue to partner with NCAR and the states of Nevada, Michigan and Minnesota to demonstrate how data already resident on state fleet vehicles could be collected, processed, transmitted and used for providing motorist advisory warnings and enhancing maintenance decision support systems through the Integrated Mobile Observations (IMO) 3.0 project. The project has been helping to 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 WxDE. The vision is for both public and private decision-makers to have the benefit of decision support tools that are supported by data from millions of vehicles through the connected vehicle initiative.

Road Weather High-priority Research Areas

The RWMP has identified the following high-priority research areas for the next ITS Strategic Plan for FY 2015-2019:

- Data and Applications – Continue research on road weather sensor design and integration within vehicles; data communications and standards; data management and quality checking; interpretation of observed mobile data and proper assimilation methods for incorporation of mobile data with other observed and modeled data; and, improved methods for information display and delivery including an understanding of human factors associated with user interpretation.
- State and Local Implementation Issues – From the existing RWMP projects, get a better understanding of the barriers and opportunities for public agencies to make investments on Connected Vehicle RWM applications, including the extent of infrastructure investments.
- Multi-Modal Integration – Continue research to build the bridge between ongoing state DOT efforts and connected vehicles and automation, in accordance with updates to the National ITS Architecture.
- Architecture & Standards – Update the Connected Vehicle Reference Implementation Architecture for RWM data and applications.

- Early Stage Applications – Continue to engage the solutions developer community to research and develop applications that leverage a flexible RWM connected vehicle communications environment.
- Connected Vehicle Pilots – Create real-world environments, urban and rural, in which public- and private-sector cooperation in implementation can educate the deployment community on the opportunities for replicating deployment.
- Data Exchange Facilitation & Interoperability – Continue to coordinate, internationally and domestically, information sharing specifications, architecture, and standards necessary for enhanced road weather data sharing across the public and private sectors within the transportation and meteorological communities. Develop and promote strategies that will foster interoperability among agencies for ingesting and disseminating weather data more universally.
- Surface Modeling – High spatial and temporal resolution surface modeling (integration of national weather prediction, pavement, traffic, and maintenance operations models)
- Vehicle Automation – Continue to understand the impact of road weather in connected vehicle automation and role of automation-enabled road weather applications in improving safety, mobility and environment.
- Expanded Regional Pilots – Demonstrate data management capabilities to support multi-modal RWM operations and data fusion, including crowd-sourced information.
- Climate Change and Sustainability – Climate change, especially meeting the information needs during extreme weather events, and role of ITS in meeting the needs. Analyzing and anticipating the effects of climate change will ensure sustainable activities and strategies for deployment and operational decisions related to the ITS environment.

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.

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 2015, deployment began on a limited basis in some US cities. Research is also being conducted on the use of mobile weather data for traffic management.

'Pathfinder' is a joint FHWA-National Weather service (NWS) project for improving transportation safety, mobility and economic productivity through cross-agency collaborative road weather information and messaging services. In this collaborative model, meteorologists at NWS Weather Forecasting Offices (WFOs) work directly with weather operations

personnel/meteorologists at DOTs and/or their private weather forecast firm before, during and after adverse weather events. The objective is to share information and develop a consistent public road weather message which highlights the travel impacts expected from any given weather event and provides decision support to public motorists. The states of California, Nevada, Utah and Wyoming were chosen to serve as a testbed for the documentation and evaluation of this collaborative model for a single winter season. These states were chosen not only because previous communication channels had been established between the State DOTs via the I-80 Corridor Coalition, but also because each of these four states represents a different DOT-private weather service provider relationship that conveniently spans the range of DOT-private scenarios among the nation's DOTs. This four-state testbed will be vital to providing guidance to other DOTs as they apply the collaborative model to their own operational scenarios. Upcoming activities include drafting guidance for cross-agency collaboration, and evaluating the guidance over the 2015-2016 winter.

The Weather-responsive Traffic Management Program has deployed three systems for evaluation in 2015-2016. They are described below:

- The South Dakota DOT deployed their FHWA-funded weather responsive traveler information system. The system includes enhanced travel information on 511, SafeTravelUSA website, and the Android mobile app. The enhanced information includes National Weather Service Alerts, temperature and wind information accompanying camera images originating from Environmental Sensor Stations and potential road condition "threats" within the next 24 hours derived from Maintenance Decision Support System forecasts.
- The Wyoming DOT Mobile Road Condition Reporting Application, recently developed through a FHWA sponsored project, has been installed on more than 20 tablets in 2 districts in Wyoming. The application allows snow plow drivers to report road weather conditions and other information directly to the TMC using the tablets.
- The Michigan DOT deployed their FHWA-funded weather responsive traveler information system, WxTINFO – Weather Traveler Information. The system utilizes NWS models, radars, forecasts, and advisories, watches, & warnings; and State owned environment sensor stations (ESS) and mobile observations. These data are input into the system and determines locations that are affected, sends messages to the TMC with the associated DMS locations for posting. In addition, the system supports messages for the State's traveler information website, MiDrive.

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 in truck heavy corridors/regions. 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.

DOT/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 (NOS)

Marine Transportation Research

Ocean Systems Test and Evaluation Program (OSTEP). OSTEP facilitates the transition of new oceanographic and meteorological sensors and systems to an operational status, in support of the NWLON and PORTS® programs. OSTEP tests instruments to ensure that they meet NOS requirements, develops operational deployment and implementation processes, and establishes quality-control criteria. OSTEP also develops defensible justification for the selection of instruments used for CO-OPS installations, and subsequent validation procedures for the devices traceable to U.S. National Standards or other accepted standards. 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. OSTEP also approved a new microwave water level sensor which is now being implemented across the NWLON as a replacement for the acoustics water level sensors. The new technology is more accurate, cheaper and easier to maintain.

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

Interagency Collaborative Programs and Products

Fire Weather Services in the National Coordination Structure for Wildland Fire Management

Wildland fire weather services are integral to wildland fire management. Wildland fire weather services enable emergency managers and state and local decision makers to understand the influences of weather and other atmospheric conditions on fire in the environment, and to make effective decisions about fire management and control.

National Wildfire Coordinating Group

The National Wildfire Coordinating Group (NWCG) is a collaborative group of intergovernmental partners with a shared vision and national responsibilities for wildland fire management. The partners focus on firefighter and public safety by improving coordination and integration through sharing talents, information, and resources. The NWCG develops and maintains standards, qualifications and training for use by its member organizations. The NWCG enables member agency efforts to be consistent and coordinated while working collaboratively toward common goals. The Executive Board of the NWCG includes 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 three entities with responsibility for wildfire management on non-Federal forest lands: the National Association of State Foresters (NASF), the Intertribal Timber Council (ITC), and the International Association of Fire Chiefs. Oversight, policy coordination, and strategic direction for NWCG are provided by a series of federal and non-federal groups from the senior executive to the fire program levels.

The NWCG is organized into four branches, fourteen committees, and numerous subgroups, representing the many business areas of wildland fire (e.g. aviation, equipment, fuels, and 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 Planning Branch. This Committee has chartered several permanent subcommittees:

- 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 Fire Behavior Analysts working closely with Incident Meteorologists on incidents.
- The Fire Environment Core Curriculum Subcommittee provides technical expertise to the Training Branch to support the NWCG fire environment training courses.

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).

Figure 1: Entrance to the NIFC in Boise, showing the logos of the participating Federal agencies and the National Association of State Foresters.

National Interagency Fire Center

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 eleven geographic areas, and 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.

NOAA/National Weather Service

The National Weather Service (NWS) Fire Weather Services support Federal, state, and local land management, supporting partners such as the Department of Interior and the Department of Agriculture. On the national level, both the Analyze, Forecast and Support (AFS) Office and NWS Office of the Chief Operating Officer (directly support tactical and strategic operations at NIFC. Also nationally, the NWS Storm Prediction Center issues assessments in advance of the development of critical fire weather patterns up to 8 days in advance. NWS Weather Forecast Offices (WFOs) also issue 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 weather conditions creating extreme fire behavior. Finally, on a request basis, NWS forecasters issue spot forecasts for specific fire incidents, prescribed burn projects or other all-hazard incidents. In addition, the National Center for Environmental Prediction produces high resolution model guidance for winds, relative humidity, convection, precipitation and heat that may impact fire growth and environmental smoke transport over the next 3-6 hours.

Upon request, NWS also provides on-scene assistance at large wildfires or other disasters, including hazardous materials 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, in some cases, 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, National Science and Dissemination Meteorologist 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) . Recent improvements also include the creation of two fire weather specific gridded weather elements, 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.

USDA/U.S. Forest Service

The U.S. Forest Service (USFS) uses meteorological data for wildland fire decision support. The Forest Service Fire and Aviation Management (FAM) program operates a network of approximately 960 remote automated weather stations (RAWS) in a national network of over 2600 stations. The network provides real-time information which forms the foundation for the, Weather Information Management System (WIMS) used widely by fire agencies across the country. The data collected are critical to strategic and tactical wildfire decision-making, including use in the Wildland Fire Decision Support System, fire behavior and effects applications, and for decision-making during prescribed fire operations.

The program provides liaison with the Satellite Telemetry Interagency Working Group (STIWG) and its associated Technical Working Group and with the National Weather Service (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 also manages the Interagency RAWS website (http://raws.fam.nwcg.gov). The information from RAWS forms the basis for fire danger assessments, pre-positioning of firefighting assets, and conducting prescribed fire operations. Costs for the program include maintenance and support contracts, training and certification sessions, contracts for synthesis and delivery of information to wildfire responders, fire weather forecasters, and state and local governments that use the data in real-time for critical decisions.

The agency 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 to oversee the five Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) locations. This effort, in cooperation with NOAA and the Environmental Protection Agency, 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.

Figure 2: Wildland fires in the wildland-urban interface are a continuing threat to lives and property.

Forest Service FAM has also initiated the Wildland Fire Air Quality Response Program to address increasingly severe smoke impacts from wildfires. The Program encompasses a national emergency response cache of smoke monitoring and meteorological equipment which display data to internal decision-makers as well as the public through an array of websites including EPA's AirNow. This program has developed a cadre of interagency Air Resource Advisors who are available for deployment to wildfire incidents to provide immediate air quality impact information, monitoring, predictive smoke modeling and collaboration with states and communities affected by smoke. Operational smoke modeling by Air Resource Advisors includes state of the art modeling capacity from Forest Service R&D that operates at fine spatial scales and includes sufficient temporal depth for proactive decision making. The Program also coordinates and collaborates with CDC, EPA and many states in guiding air quality response to wildfire smoke impacts.

The Wildland Fire Decision Support System (WFDSS) integrates state of the art science and technology in support of risk-informed decision making (wfdss.usgs.gov). It is a web-based system that integrates vegetation, topography, weather, and property and infrastructure data used to evaluate wildfire risk, conduct analysis, complete operational plans, and document decisions for all wildland fires. It facilitates access to a diverse set of analytical tools in the areas of fire behavior modeling, fire weather information, economic assessment, air quality and smoke management, and information technology to support efficient and effective wildland fire decisions consistent with federal and non-federal natural resource and wildland fire management plans and community wildland fire protection plans. The WFDSS greatly reduces the time to assemble and evaluate large databases by using comprehensive enterprise databases in a spatial context. The system also incorporates a progressive decision documentation and analysis process that can be scaled and adapted to match incident specific requirements and 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. WFDSS is continually upgraded to provide more useful information, easier to use applications, and data updates (wfdss.usgs.gov/wfdss/pdfs/Need2Know_2015.pdf).

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 (RAWS) location to derive forecasted weather data. This forecast information, along with geospatial data provide by the USGS are used to derive live and dead fuel moisture characteristics and wind conditions to aid in the prediction of fire behavior.

Landslides Hazards Program. Debris flows and flash floods that originate from steep watersheds burned by wildfire pose considerable hazards to downstream communities and structures. Fires throughout the western U.S. have impacted hundreds of thousands of acres of public land and made it susceptible to increased runoff and debris-flow activity. Science-based information on post wildfire debris-flow hazards is critically needed by Federal, State, and local agencies to issue warnings and to mitigate the impacts of post-fire hazards on people, their property, and natural resources. A joint NOAA/USGS, flash flood and debris flow warning system for recently burned basins in southern California was established in 2005 by linking the existing NWS Flash Flood Monitoring and Prediction (FFMP) system with rainfall intensity-duration thresholds for burned areas developed by the USGS. Such a system is being used to issue Outlooks, Watches and Warnings that are disseminated to emergency-management personnel and the public through the NWS existing protocol. The USGS has also developed models for characterizing potential post-fire debris flow susceptibility that, when compared with forecast or measured precipitation, have been used to generate maps of potential hazards in real-time, which have been disseminated to the Federal Emergency Management Agency (FEMA) and the public through existing NWS protocol. The USGS has also developed models for characterizing potential post-fire debris flow susceptibility that, when compared with forecast or measured precipitation, have been used to generate maps of potential hazards in real- time, which have been disseminated to FEMA and to State and local agencies. Since its inception, numerous advisories have been given to residents and public officials, resulting in saved lives and reduced property damage.

SUPPORTING RESEARCH PROGRAMS AND PROJECTS

Department of Agriculture

U.S. Forest Service

The research and development (R&D) mission of the USFS is to develop and deliver knowledge and innovative technology to improve the health and use of the Nation's forests and grasslands—both public and private. R&D provides this information to landowners, managers, policymakers, and the American people to help inform their decisions and actions. USFS researchers work independently and with a range of partners to provide land managers with information and technology to make management and land use decisions on issues such as invasive species, healthy watersheds, wildfires, climate change, and traditional and alternative forest products. The USFS R&D workforce includes scientists and technicians in the biological, physical, and social science fields, working in partnership with researchers from other agencies, academia, nonprofit groups, and industry. A few of the key accomplishments:

- A study of climate change and land-use change impacts on fire weather and fire behavior in the eastern U.S. using regional-scale climate models. Forest service research used climate change projections from the North American Regional Climate Change Assessment Program to assess where changing climate conditions in different regions of the U.S. could result in fire-weather conditions more conducive to extreme or erratic fire behavior. Results have improved understanding of potential effects that climate and land-use change have on the frequency of large and more extreme fires in the eastern U.S. because of more conducive fire-weather and fuel conditions.
- Comparison of smoke models. Forest Service scientists designed the Smoke and Emissions Model Inter-comparison Project to examine requirements for fire emissions and smoke impact modeling and conduct baseline comparisons between existing models and develop standard approaches for evaluating the operational capacity of new models. Results indicate lack of fire occurrence data quality for small fires is a major source of uncertainty for emissions inventories. The varying quality of wildland fuels maps used as input for modeling applications imposes a major source of uncertainty even in national annual emissions totals. Recently two major data development projects have been funded to address this issue. The complex dynamics of smoke plumes that form over wildland fires pose a significant challenge to correctly predicting air quality impacts.
- Forest service research is using emerging technologies such as airborne LiDAR to quantify and predict the dynamics of smoke plumes and associated transport processes to reduce uncertainty in determining the impacts of wildfire emissions on air quality and public health and safety. The research addresses gaps in parameterizing and validating smoke transport models and quantitatively defines uncertainties, biases, and limits in existing and emerging applications. Results indicate that previous estimates of wildfire emissions may have underestimated the production of pollutants and, therefore, the potential of wildfire to degrade air quality.
- The Forest Service Planning Rule requires national forests to consider air quality when developing plan components and to consider air resources consistently with soil and water resources. Forest Service managers use applications developed by *Forest Service* researchers to measure or estimate the amount of atmospheric deposition occurring on National Forests

and if the amount of deposition affects forest resources. With this requirement in mind, an Air Quality Portal has been developed as an online decision management tool to assist forest managers in evaluating air pollution impacts on their landscapes. By creating an easy-to-use resource to facilitate consideration of air resources for forest planning, we ensure a nationally consistent methodology which incorporates the best available science and data and eases the burden on land managers. Briefings and presentations have demonstrated and advertised this tool to internal and external staffs and organizations. Internal feedback has focused on using the Air Quality Portal as a model for providing guidance on forest planning in other resource areas. External feedback has focused on expanding availability of the tool for management use in other agencies and organizations, because the Portal is currently only available on the FS intranet.

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 through its Applied Science Program element of the Earth Science Division (ESD). These projects serve as a bridge between NASA-generated data, derived products, information, knowledge and the 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.

Wildland Fire Weather Applications: New Opportunities. In FY 2015, the NASA ESD, Applied Sciences Program completed their first year of the nine funded Phase II Wildfire Applications Projects. During the Phase II developments the projects are expected to successfully transition their capabilities to operational use by partner organizations. Partner organizations are expected to ramp-up their support and provide operational continuity of the transitioned capabilities. The projects advancing to Phase II focused on fire-related multidisciplinary topics including health and air quality, ecological forecasting, fire weather, water resources, disasters, and climate, and addressed all stages of wildland fire activities (pre-fire, active-fire, and post-fire assessment). In FY16, the projects are expected to provide baseline data, models and information, in a quasi-operational environment, allowing early assessment of adaptation by their partners. By the end of FY17, the projects are expected to have operationalized / transitioned their models, tools, and information sets, for use by their partner organizations.

Of the nine selected Phase II wildland fire applications projects, four had a focused fire-weather forecasting and modeling component. Those four projects are highlighted here:

- *Wildland Fire Behavior and Risk Forecasting* focuses on improving forecasting of wildland fire behavior and risk through inclusion of NASA / NOAA remote sensing observations, integrated within NOAA fire weather forecasting systems. The system is based on a coupled atmosphere-wildland fire model, which combines the Weather Research and Forecasting model (WRF) with a fire spread model (WRF-SFIRE) and a dynamic fuel moisture model. Dynamic data from NASA and NOAA orbital platforms (moisture estimation, burn scar mapping, and fire detection) are assimilated into the simulations. The system is accessed through NOAA FX-Net system or a website, and downloadable KML files for visualization in Google Earth. Expected operational partners to advance the capabilities include NOAA, US Forest Service and BLM.

An Integrated Forest and Fire Monitoring and Forecasting System for Improved Forest Management in the Tropics focuses on development of a near-real-time alert system (FireCast) for use in non-traditional partner countries (such as Bolivia, Peru, Madagascar, and Indonesia) to enable improved fire monitoring, forecasting and improving monitoring of illegal forest activities (harvesting, burning, etc.). Firecast will include monitoring by NASA / NOAA orbital observation assets (MODIS, VIIRS, and Landsat) and development of fire risk models based on observed vegetation condition class and fire weather variables. Firecast will make a strong contribution to enhancing conservation and sustainable development goals for each of the target countries.

- *TOPOFIRE: A System for Monitoring Insect and Climate-Induced Impacts on Fire Danger in Complex Terrain* integrates NASA remote sensing and climate products into a decision support tool that delivers a suite of high spatial resolution real-time information essential to wildland fire management. Data from thousands of temperature and humidity sensors distributed across the US will enable refinement of the North American Land Data Assimilation System (NLDAS) downscaling algorithms, and the generation of high resolution historical and real-time gridded climate datasets. The fire spread simulator FARSITE will be modified to assimilate gridded microclimate data, which will be coupled with high resolution hydrologic outputs to produce on-demand fire behavior simulations that account for topo-climate and disturbance-induced structural change. Crowd-sourced weather and fuels information from incidents will be assimilated into hydro-climatic and fire behavior models, returning terrain and location-corrected fire behavior and incident risk information via smart phone to the firefighter.
- *Development and Application of Spatially Refined Remote Sensing Active Fire Data Sets in Support of Fire Monitoring, Management and Planning* builds on proven science algorithms to produce new spatially refined active fire detection satellite products that yield significantly improved fire information. In addition, these products are used to initialize and validate fire growth predictions in a coupled weather-fire model that accounts for fuel information NASA / NOAA orbital sensors) and weather forecasts (including wind forecasts) to optimize the modeled outputs. The significance is that this approach can now be applied to monitor and predict the growth of a fire or a group of simultaneous wildland fires in a management unit from first detection until containment. The project focuses on near real-time operational delivery of new satellite remote sensing fire data, including customized products tailored for the end user community. Key partner agencies include the USDA Forest Service and the National Weather Service.

Each of these projects will result in an improvement in the capacity of the fire management community to monitor, model, predict and manage fire behavior to reduce impacts on the community and still optimize ecological balances and benefits that fire can provide. The integration of fire weather information and models can and will improve our capacity to understand fire interplay in the ecosystem.

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 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) 30th and 45th Space Wings, 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 Kennedy Space Center (KSC) and NASA programs operating from KSC or the Eastern Range.

The ELV program operates from many locations, including Cape Canaveral Air Force Station (CCAFS) in Florida, Vandenberg Air Force Base (VAFB) in California, NASA Wallops Flight Facility (WFF) in Virginia, the Alaska Aerospace Corporation Pacific Spaceport Complex – Alaska (PSCA; formerly Kodiak Launch Complex) in Alaska, 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 criteria (LFCC) at commercial spaceports.

In FY 2015, the KSCWO:

- Supported the Tri-Program through infrastructure and requirements concept studies for the Space Launch System (SLS), Multi Purpose Crew Vehicle (MPCV), Ground Systems Development and Operations (GSDO), and Experimental Flight Test 1 (EFT-1)
- Supported NASA ELV launches from NASA/WFF and 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/WFF
- Supported the Morpheus Lander Project by providing forecasts and weather consultations from the USAF 45th Weather Squadron for multiple Morpheus test firings at KSC
- Support installation and certification testing of the new 50-MHz Doppler Radar Wind Profiler (DRWP)
- Supported the Lightning System Upgrade (LSU) on the Eastern Range for data communication and validation
- Continued assisting the FAA with the development of LFCC for the commercial sector

In FY 2016, the KSCWO will:

- Continue to support the ELV program
- Continue to support NASA/WFF, PSCA, 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 LFCC for the commercial sector
- Support the Tri-Program, and continue support for planning and design of the test flight programs
- Continue to work with the Eastern Range and other Ranges to define the requirements and infrastructure for weather support to NASA ELV and manned spacecraft in the post-Shuttle era

Spaceflight Meteorology Group

The SMG is located at NASA/JSC. In FY 2015, the SMG:

- Operated with significantly reduced staff of 1 meteorologist
- Provided consultation on the Orion/MPCV, including post-EFT-1 analysis
- Supported Orion parachute drop test events at Yuma Proving Ground and near Eloy, 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
- Provided the NASA/Langley SCIFLI project cloud forecasts for thermal imaging of commercial launch vehicles as requested
- Provided support for several large outdoor events at JSC
- Provided ongoing lightning and severe weather customized advisories for JSC management, weather sensitive operations, and employees

- Began landing site climatology studies and other pre-operational planning consultation for other missions scheduled to be controlled from the JSC Mission Control Center (MCC)

In FY 2016, SMG will:

- Provide consultation on the Orion/MPCV
- Participate in NASA/JSC MCC landing simulations for Orion/MPCV
- Continue consultation with commercial crew mission scheduled to be controlled from the JSC MCC
- Implement AWIPS II enhancements focused upon Orion/MPCV, other manned programs and JSC specific support
- 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
- Provide weather support to large outdoor events at JSC
- Provide lightning, severe weather, and tropical storm/hurricane customized advisories for JSC management, weather sensitive operations, and employees

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 real-time mission impacts of adverse space weather conditions. Some of the key space weather-related activities that SRAG is conducting in FY 2015 and FY 2016 include:

- Daily monitoring of the space weather environment and impact assessment for crewed missions.
- Developing and maintaining protocols for radiation environment contingency response and analysis.
- Operating instruments both internal and external to crewed spacecraft for radiation environment characterization, quantification and impact assessment.
- Building and processing of crew worn passive dosimeters and maintaining all crew radiation exposure records.
- Design and Development of next generation radiation sensors that reduce mass, volume, and power without compromising data integrity.
- Developing collaborations for maintaining necessary space radiation measurements for instruments operating beyond planned lifetimes.
- Leading the development of space weather forecasting models.
- Transitioning maturing space weather forecast models from research to operations.
- Leading development of state-of-the-art radiation transport tools for vehicle design radiation analysis.
- Implementing state-of-the art radiation risk models used to ensure astronauts are within lifetime career radiation risk limits.

- Providing annual, end-of-active service, and ad hoc astronaut radiation risk reports.

Marshall Space Flight Center

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

In FY 2015, the NEB:

- Continued to develop terrestrial environment specifications, and provide atmospheric data and models for vehicle design and operation for the SLS and MPCV programs
- Developing preliminary day-of-launch procedures relating to upper air wind and thermodynamic requirements for the SLS and MPCV programs
- Providing insight into the atmospheric data and models used for vehicle and operations design for the Commercial Crew Program (CCP)

In FY 2016, 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
- Continue developing day-of-launch procedures relating to upper air wind and thermodynamic requirements for the SLS and MPCV programs
- Continue to provide insight into the atmospheric data and models used for vehicle and operations design for the CCP

U.S. Air Force Space Launch Support

Air Force weather organizations provide 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. AF weather organizations also provide tailored forecasting for NASA's manned and unmanned launches and for commercial launches from KSC. In addition, AF weather personnel provide specialized meteorological information for the Air Force Western Range at Vandenberg Air Force Base (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 Department of Defense (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)

The RTS meteorological services contractor provides support for range activities, including local and remote missile launches, missile weapons readiness testing, and aviation, marine, and emergency operations.

A full suite of meteorological surface, upper air, satellite, radar, and lightning observing systems are available. Surface systems include an intra-atoll mesonet and an FAA-approved Automated Weather Observing System (AWOS III-P/T), supporting range and International Civil Aviation Organization at Bucholtz Army Airfield (AAF) and an automatic meteorological observing system at Dyess AAF. 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. The Polar-orbiting Operational Environmental Satellite (POES) satellite receiver at Kwajalein is in the process of being replaced by a new X- and L-band dual frequency system that will provide the Range with multiple satellite capability for cloud detection, movement, analyses and one geostationary satellite receiver, with data processing and analysis provided through McIDAS management and display supporting all systems. A low-gain lightning detection network of four sensors is available to the RTS meteorologist in support of Kwajalein Atoll. 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 at Bucholtz Army Airfield. RTS provides rocketsondes locally and at remote locations where radar tracking can support.

Figure 1: A rocketsonde launch on Kwajalein Atoll. U.S. Army Photo.

In cooperation with NASA Goddard Space Flight Center, RTS Weather continues to support global climate studies through Global Precipitation Measurement. Solar-Earth radiation fluxes monitoring with a suite of radiation measurements systems began in 1989 and are being reestablished by NOAA'S Earth Systems Research Laboratory (ESRL).

National Park Service/Fish and Wildfire Service

NPS Air Quality and Visibility Monitoring

The National Park Service (NPS) monitors air quality and visibility in a number of national parks and monuments. Gaseous pollutant data are collected on continuous and integrated (24-hour to weekly) bases. Surface meteorological data are collected and analyzed for hourly averages. Precipitation chemistry is determined on week-long integrated rainfall samples. Twenty-four-hour-average particle concentrations (mass, elemental analyses, some chemical constituent analyses) are measured every third day. Atmospheric light extinction is measured continuously and relayed to a central location for analyses.

Joint Air Quality Monitoring

The 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.

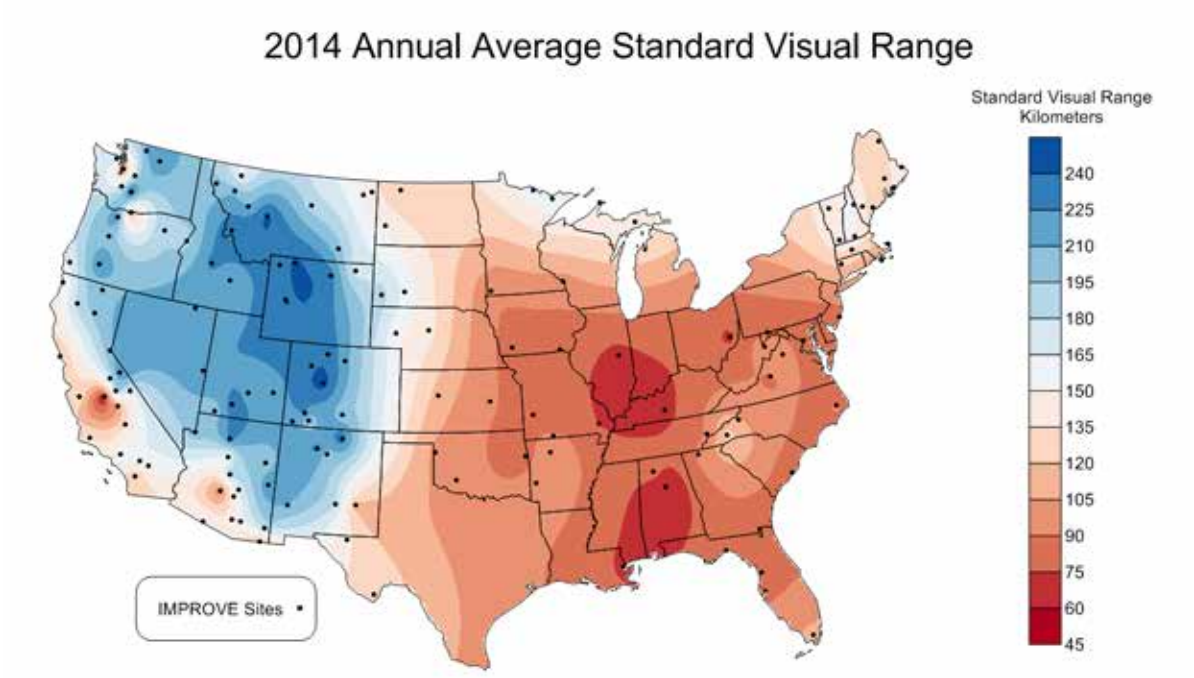


Figure 2: Map of one-year average standard visual range (SVR) from 2014, in kilometers, calculated from IMPROVE particle concentrations. Also shown are the locations of most of the IMPROVE and IMPROVE protocol sites in the contiguous U.S.

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 165 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 on previous page).

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 during 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 extreme meteorological events over a range of timeframes, including long-term events greater than 100 years, to evaluate new reactor designs and sites, as well as existing and operating reactor locations. In FY 2015, the NRC has also seen a need to understand even rarer phenomenon, such as maximum precipitation events on even longer timeframes. 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 Office of Nuclear Material Safety and Safeguards conducts similar reviews of materials and waste facilities. All of 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

The U.S. Army Research Institute of Environmental Medicine (USARIEM) incorporates weather as an essential component in studying and modeling human physiology and biophysics, with the goal of improving Warfighter performance and minimizing health risks associated with environmental extremes. USARIEM and partners at U.S. Army Research Laboratory-White Sands Missile Range (ARL-WSMR) are developing methodologies for integrating real-time local environmental data and Warfighter physiological data into predictive models and Soldier-scale weather forecasting. The effective combination of these two dynamic data streams will enable real-time predictions of environmental strain and physiological status for Warfighters.

National Park Service

Air Quality Research

The National Park Service (NPS) conducts research to develop and test air quality models to assess long-range transport, chemical transformation, and deposition of air pollutants. These models are used to estimate source contributions to, and to identify source regions responsible for, observed pollutant loadings.

The NPS is conducting research in the area of atmospheric nitrogen loading to high-elevation ecosystems in the Rocky Mountains, which have documented effects from nitrogen deposition. The NPS participated in the July 2014 Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) and the Front Range Air Pollution and Photochemistry Experiment APPÉ) field campaigns taking place in the Denver, Colorado area extending into the mountains, which includes Rocky Mountain National Park. Measurements of oxidized and reduced nitrogen compounds, organic nitrogen compounds, a variety of volatile organic compounds, and ozone were made at the park. These measurements are being used to better understand the sources of nitrogen deposition and the contributors to high ozone. These measurements are integrated with commensurate airborne and ground measurements in the region. Analysis will continue into 2016.

NPS is also examining the effects of recent oil and gas development in North Dakota on Theodore Roosevelt National Park. Concentrations of oxides of nitrogen, ozone, volatile organic compounds and speciated fine particles were measured during a second field campaign from November 2013 to March 2014 to assess atmospheric deposition and visibility impairment at the park. Analyses were conducted in 2015 and will continue into 2016.

National Aeronautics and Space Administration

Applied Meteorology Unit

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

In FY 2015, the AMU:

- Operated with reduced staff of 2.5
- Updated, and delivered, the AMU developed Weather Tower Climatology Tool used by the 30th Operations Support Squadron (OSS) at Vandenberg Air Force Base (VAFB) to include four additional sensor levels.
- Completed the LSP Upper Winds Tool upgrade to include implementation of the algorithm to splice the 915-MHz DRWP with the 50-MHz DRWP now that the new 50-MHz DRWP is providing real time data.
- Set up the new AMU-WRF with expanded model domains to run in real-time. The new domains include the 12-km domain to cover the state of Florida including both coasts and extends just east of the Bahamas, the 4-km domain to cover the east and west coasts of

Florida from St. Augustine to Fort Lauderdale, and the 1.33-km domain to cover the east coast just south of St. Augustine to West Palm Beach and out west to Lakeland. This helps the 45 WS forecasters better track the west coast sea breeze before it impacts KSC/CCAFS and monitor tropical cyclones near the east coast of Florida. It also provides high resolution model forecasts for the NOAA NWS in Melbourne (NWS MLB) over their entire County Warning Area (CWA).

- During the Atlas 5 launch on 20 January, created an AMU-WRF model forecast product of percent cloud cover in a layer from 10,000 to 30,000 feet to assist the 45th WS LWO. The LWO was interested in the amount of cloud forecast at T-0 in the vicinity of the freezing level to support the thick cloud rule and triggered lightning rule launch commit criteria. The AMU-WRF forecast the clouds to clear by T-0, which they did.
- Supported launch operations for three Atlas V, two Delta IV and five Falcon 9.

In FY 2016, the AMU will:

- Possibly operate with reduced staff
- Analyze and compare the upper level winds from the 50-MHz DRWP against the CCAFS rawinsonde (sounding balloon) data as part of the long-term operational acceptance test
- Partner with the NWS MLB to develop a real-time triple-Doppler radar wind field display for operational analysis and model input
- Support launch operations for Atlas V, Delta IV and Falcon 9.

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 and building downwash.

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, is scheduled for release during the fall of 2015. 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 website 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.

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 dispersion
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
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions
CEISC	Committee on Environmental Information Systems and Communications
CENR	[NSTC] Committee on Environment and Natural Resources
CENRS	[NSTC] Committee on Environment, Natural Resources, and Sustainability
CERIS	Coastal, Estuary Resource Information System

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

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

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

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

ISR	intelligence, surveillance, and reconnaissance
ISS	International Space Station
IT	information technology
IT R&D	Information Technology Research and Development [Program]
ITS	Intelligent Transportation Systems
ITWS	Integrated Terminal Weather System
IWEDA	Integrated Weather Decision Aid
IWGCCST	Interagency Working Group on Climate Change Science and Technology
IWRSS	Integrated Water Resources Science and Services
JAG	Joint Action Group
JAG/ADM	Joint Action Group on Architecture and Data Management (
JAG/CCM	Joint Action Group for Centralized Communications Management
JAG/JUTB	Joint Action Group for Joint Urban Test Beds
JAG/MD	Joint Action Group on Metadata
JAG/OCM	Joint Action Group for Operational Community Modeling
JAG/ODAA	Joint Action Group for Operational Data Acquisition for Assimilation
JAWF	Joint Agricultural Weather Facility
JAWS	Juneau Airport Wind System
JCIDS	Joint Capabilities Integration and Development System
JCSDA	Joint Center for Satellite Data Assimilation
JHT	Joint Hurricane Testbed
JPDO	Joint Planning and Development Office
JPSS	Joint Polar Satellite System
JSC	[NASA] Johnson Space Center
JTWC	Joint Typhoon Warning Center
KDP	Key Decision Point
KSC	[NASA] Kennedy Space Center
KSCWO	SOMD Weather Office at NASA Kennedy Space Center
LAN	local area network
LAP	Lightning Advisory Panel
LBS	Littoral Battlespace Sensing
LDCM	Landsat Data Continuity Mission
LIDAR	light detection and ranging
LLCC	lightning launch commit criteria
LLWAS	Low Level Wind shear Alerting System
LLWAS-NE	LLWAS Network Expansion
LRGS	[USGS] local readout ground station(s)
M&O	management and operating
MACPEX	Mid-latitude Airborne Cirrus Properties Experiment
MADA	Monsoon Area Drought Atlas

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

NDFD	National Digital Forecast Database
NDMC	National Drought Mitigation Center
NEB	Natural Environments Branch [MSFC]
NESDIS	[NOAA] National Environmental Satellite, Data, and Information Service
NEXION	NEXt-generation IONosonde
NEXRAD	Next-Generation Weather Radar
NextGen	Next Generation Air Transportation System
NFDRS	National Fire Danger Rating System
NFIP	National Flood Insurance Program
NGA	National Geospatial-Intelligence Agency
NGDC	National Geophysical Date Center
NGEE	Next-Generation Ecosystem Experiments
NHC	[NCEP] National Hurricane Center
NICC	National Interagency Coordination Center
NIDIS	National Integrated Drought Information System
NIFA	National Institute for Food and Agriculture
NIFC	National Interagency Fire Center
NITES	Navy Integrated Tactical Environmental System
NNEW	NextGen Network Enabled Weathe
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NOCMP	National Operational Coastal Modeling Program
NODC	National Oceanographic Data Center
NOGAPS	Navy Operational Global Atmospheric Prediction System
NOHRSC	National Operational Hydrologic Remote Sensing Center
NOMADS	National Operational Model Archive and Distribution System
NOP	Naval Oceanography Program
NOPC	National Operational Processing Centers Program Council
NORAD	North American Aerospace Defense Command
NOS	National Ocean Service
NOWCON	Network of Weather and Climate Observing Networks
NPDIA	National Plan for Disaster Impact Assessments: Weather and Water Data
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NPRB	North Pacific Research Board
NPS	National Park Service
NRC	Nuclear Regulatory Commission; National Research Council
NRCC	[FEMA] National Response Coordination Center
NRCS	Natural Resources Conservation Service
NRL	Naval Research Laboratory
NRL/MRY	Marine Meteorology Division of the Naval Research Laboratory [NRL Monterey]
NSF	National Science Foundation
NSIP	National Streamflow Information Program
NSIR	Office of Nuclear Security and Incident Response

NSPD	National Security Presidential Directive
NSSL	[NOAA] National Severe Storm Laboratory
NSWP	National Space Weather Program
NSWRC	NextGen Surveillance and Weather Radar Capability
NTAS	Northwest Tropical Atlantic Station
NTHMP	National Tsunami Hazard Mitigation Program
NUOPC	National Unified Operational Prediction Capability
NWCG	National Wildfire Coordinating Group
NWIS	National Water Information System
NWLON	National Water Level Observation Network
NWP	numerical weather prediction
NWR	NOAA Weather Radio
NWRT	National Weather Radar Testbed
NWS	[NOAA] National Weather Service
OAR	[NOAA] Office of Oceanic and Atmospheric Research
OCE	(USDA) Office of the Chief Economist
ODCS	[U.S. Army] Office of the Deputy Chief of Staff
OEP	Operational Evolution Partnership [FAA airport designation]
OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OGC	Open Geospatial Consortium
OMAO	[NOAA] Office of Marine and Aviation Operations
OMB	Office of Management and Budget
ONR	Office of Naval Research
OPC	Ocean Prediction Center
OSSE	observing system simulation experiment
OSTEP	Ocean Systems Test and Evaluation Program
OSTM	Ocean Surface Topography Mission
OSTP	Office of Science and Technology Policy
OTN	[Defense Information Systems Agency] Optical Transport Network
OTSR	Optimum Track Ship Routing
OWS	[USAF] Operational Weather Squadron
P3I	Pre-Planned Product Improvement
PACAF	Pacific Air Forces
PARISE	Phased Array Radar Innovative Sensing Experiment
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PLAN	Personal Localized Alert Network
PMEL	Pacific Marine Environmental Laboratory
PNE	PIRATA Northeast Extension [project]
POD	probability of detection
POES	Polar-orbiting Operational Environmental Satellite
POP	Parallel Ocean Program [DOE/OS/CESD model]
POPS	Primary Oceanographic Prediction System

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

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

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

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

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