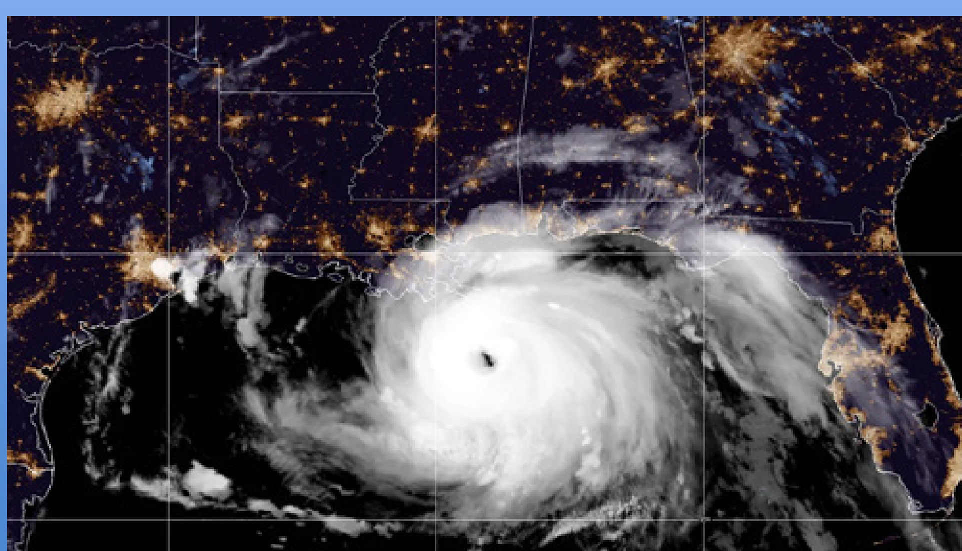
Office of the Federal Coordinator for Meteorology

(OFCM)

Retrospective

2014-2021

August 2022



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Cover Image: Hurricane Ida, seen here on 29 August 2021. NOAA and USAF aerial reconnaissance coordinated through the OFCM National Hurricane Operations Plan Credit: NOAA, Public Domain

Foreword

In 2014, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) celebrated its 50th anniversary as the focal point for interagency collaboration and cooperation among the Federal departments and agencies in developing and providing weather, climate, hydrological, and space weather services for our Nation. As an organization aligned under the National Oceanic and Atmospheric Administration (NOAA), the ceremony was hosted by the Undersecretary of Commerce for Oceans and Atmosphere, Dr. Jane Lubchenco, and attended by the Director of the National Aeronautics and Space Administration, Mr. Charles Bolden, by White House and Congressional staff, and by over 200 members of the civil and Federal weather enterprise.

The accomplishments of OFCM in fulfilling its mission to coordinate and report to Congress on Federal meteorological efforts are well documented in the publication, *The Federal Role in Meteorological Services and Supporting Research: A Half-Century of Multi-Agency Collaboration* [OFCM 2013a]. Chief among these accomplishments were creating and evolving a Federal meteorological coordinating infrastructure; coordinating the planning for and implementation oversight of the WSR-88D NEXRAD weather radar program; conducting 75 Interdepartmental Hurricane Conferences, along with annual publication of the National Hurricane Operations Plan; establishing the National Space Weather Program; and reporting annually to Congress on the budget, programs, and coordination actions of the Federal Weather Enterprise.

Since 2014, OFCM has continued to provide outstanding service to the Nation. Recent accomplishments include: interagency formulation and coordination of the Deep Space Climate Observatory (DSCOVR) mission, which expanded to a million miles into space NOAA's observational monitoring for both climate observations and critical warnings of potentially catastrophic space weather events; integrating the national Earth System Prediction Capability into the Federal meteorological coordinating infrastructure; and implementing the White House–led development of the Interagency Council for Advancing Meteorological Services (ICAMS)—the largest reorganization of Federal Meteorological coordination in the past 50 years, for which OFCM earned the NOAA Administrator's award.

This document completes the historical record of the service and accomplishments of OFCM during the period from 2014 through its closure in 2021. I proudly recognize the significant achievements of OFCM as we pass the mantle of Federal coordination to ICAMS and its supporting office, the Interagency Meteorological Coordination Office.

Michael F. Bonadonna
Director, Office of the Federal Coordinator for Meteorology (2018-2021)

Contents

OFCM Retrospective, 2014–2021

1. Introduction

From 1964 through 2021, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM)[1] served as the primary agent responsible for coordinating the diverse Federal programs and activities intended to advance national meteorological services. Throughout its 57-year history, OFCM has facilitated cooperation among the agencies of the Federal government and provided a focal point for our national efforts.

The many challenges and accomplishments of the OFCM through 2013 are documented in the *The Federal Role In Meteorological Services And Supporting Research: A Half-Century of Multi-Agency Collaboration* [OFCM 2013a]. It contains a complete history of the efforts taken by the U.S. government to improve meteorological capabilities through interagency coordination from 1964 through 2013. That report included a timeline table (Appendix E) showing the terms of service for the Federal Coordinators for Meteorology and Deputy Federal Coordinators from OFCM's start in 1964 through 2013. Appendix 2 to this report extends that table of terms of service to cover the entire duration of OFCM.

As the tenure of OFCM came to a close in 2021, it became clear that an effort should be made to document the final eight years of OFCM activities. This report focuses on the years 2014 through 2021 but also references activities initiated prior to that period, to provide context. It is intended to highlight the accomplishments from interagency coordination that OFCM facilitated in key areas such as executive branch input to formulation of the *Weather Research and Forecasting Act of 2017* (hereafter, "Weather Act of 2017"), space weather, the national weather radar program, coordination of tropical cyclone (hurricane) operations and research, coordination among the Nation's operational processing centers, and post-disaster impact assessment.

2. OFCM and the Weather Act of 2017

Title IV of the Weather Act of 2017 addresses interagency weather research and forecast innovation coordination. OFCM greeted the law with enthusiastic support, since it provided a long-sought signal to other Federal agencies about the mission and validity of the office. However, the Weather Act of 2017 imposed two significant changes in OFCM's day-to-day coordination efforts. First, the Office of Science and Technology Policy (OSTP), in the Executive Office of the President, was congressionally mandated to play a leading role in the coordination of Federal meteorological agencies. Second, the law directed the establishment of an Interagency Committee for Advancing Weather Services (ICAWS), to improve coordination of relevant weather research and forecast innovation activities across the Federal government. The act specified that ICAWS members would include the Federal Aviation Administration (FAA), National Aeronautics and Space Administration

[1] Appendix 1 is a list of acronyms and abbreviations used in this document.

(NASA), National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), and "other agencies…as the President determines are appropriate."

The newly mandated ICAWS bore a strong resemblance to the existing Federal Committee for Meteorological Services and Supporting Research (FCMSSR), a committee of senior executive representatives from the 15 Federal agencies with meteorological concerns, including the Office of Management and Budget (OMB) and OSTP. The FCMSSR was at the top of a pyramid of interagency committees, subcommittees, and working groups spanning the range of meteorology and meteorological services.

In 2018, following FCMSSR direction, OFCM and the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR)[2] established the Joint Action Group for ICAWS Implementation (JAG-ICAWS) to develop an interagency consensus on how to implement Section 402 of the Weather Act of 2017 [OFCM 2017a]. The JAG-ICAWS consisted of

The members of the Federal Committee for Meteorological Services and Supporting Research (FCMSSR), the senior oversight body for OFCM, included all the Federal Departments and agencies shown here. The Department of Defense was represented by senior officials from the Navy, Air Force, and Army. The Executive Office of the President was represented by OMB.

members from each of the agencies identified by the Weather Act of 2017, plus other key FCMSSR agencies including the Department of Defense (DOD), the U.S. Geological Survey, OSTP, and OMB. Several options were discussed and assessed over an 18-month period, culminating in a draft

[2] The ICMSSR reported to the FCMSSR and served as the highest-level interagency committee of technical-level Federal Weather Enterprise program managers in the OFCM coordination infrastructure.

ICAWS charter in the fall of 2019. The ICMSSR concurred with the draft charter, which was subsequently cleared by both NOAA and OSTP. OFCM briefed the FCMSSR chair that the ICAWS charter would be ready for NOAA and OSTP signature at the Fall 2019 FCMSSR meeting [OFCM 2019].

However, before the ICAWS charter was signed, OSTP proposed a new approach that recognized the importance of the coupled Earth systems in meteorological services. First, in consultation with Congress, the OSTP Director requested that the name be changed from "Interagency Committee for Advancing Weather Services" to "Interagency Council for Advancing Meteorological Services" (ICAMS), to align with the World Meteorological Organization's (WMO) "Earth systems" approach to meteorological services. Second, OSTP proposed establishing an entirely new coordinating infrastructure under ICAMS and replacing OFCM with the new Interagency Meteorological Coordination Office (IMCO) [Droegemeier and Jacobs 2021].

From 2019 through its retirement in 2021, OFCM played a critical role in establishing ICAMS. Preliminary discussions in early 2020 between OSTP staff and NOAA senior leaders, including the Federal Coordinator, addressed important issues of possible administrative structures and scope of the new organization. A small group of senior leaders, which eventually involved dozens of career professionals and political appointees across relevant Federal departments and agencies, met to develop the initial concepts [Droegemeier and Jacobs 2021]. The OFCM staff provided foundational support for the formation of an ICAMS coordinating infrastructure, continuity of vital legacy coordination functions, and establishment of IMCO [NOAA 2021, p. 23].

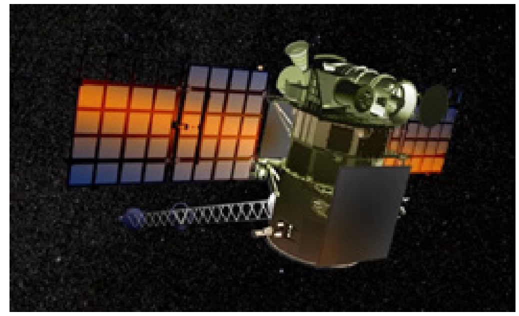
Ultimately, the FCMSSR was disbanded in December 2020, superseded by the new ICAMS, and OFCM was reorganized as IMCO in December 2021.

3. Evolution of the National Space Weather Program

On February 11, 2015, the DSCOVR spacecraft was launched from Kennedy Space Center aboard a SpaceX Falcon 9 rocket. Photo credit: NASA/Tony Gray and Tim Powers.

The evolution of the National Space Weather Program (NSWP) and its transition to the White House National Science and Technology Council (NSTC) in 2015 served as an example for the transition of Federal meteorological coordination from the OFCM-managed infrastructure to ICAMS in 2020. The substantial accomplishments of the NSWP set the conditions for the outstanding success of the Space Weather Operations, Research, and Mitigation (SWORM) Task Force, now the SWORM subcommittee codified by the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act of 2020 (Public Law 116-181).

In June 2007, OSTP saw an urgent need to ameliorate the impact of diminished space-weather sensing capabilities. OSTP asked OFCM to engage the NSWP to examine the consequences from these reductions in planned sensing capabilities on national infrastructure such as the electric power grid. The resulting report



Artist's rendering of the DSCOVR spacecraft operationally deployed in space. Credit: NOAA.

[OFCM 2008] also discussed the consequences from potential loss of solar wind data from the National Aeronautics and Space Administration's (NASA's) Advanced Composition Explorer (ACE) spacecraft, which was already well beyond its design operational life.

Following up on its 2008 report, the NSWP Council formed the Committee for Space Environmental Sensor Mitigation Options, which comprised 70 members from Federal space weather operations and research communities, to produce two reports by the end of 2009. These reports provided recommendations for solar wind and low Earth-orbit space environmental sensing capability [OFCM 2009a, OFCM 2009b]. In April 2010, the U.S. Government Accountability Office (GAO) recommended that Congress direct OSTP to release these NSWP reports [GAO 2010]. The reports and GAO's response to them provided the foundation of interagency cooperation leading to funding for the Deep Space Climate Observer (DSCOVR), which launched in 2015, and the Constellation Observing System for Meteorology, Ionosphere, and Climate–2 (COSMIC-2) mission, which launched in 2019. Other responses included enhancements to DOD's space-based space weather monitoring programs and a DSCOVR follow-on mission, the Space Weather Follow-On Lagrange-1 (SWFO-L1), scheduled for launch in 2025.

The NSWP continued its systems architecture work in 2011 with the Space Environmental Gap Analysis effort, which yielded a report for the White House in 2013 [OFCM 2013b]. This report helped NOAA, NASA, and DOD pursue an integrated approach to sustaining and improving space weather monitoring for the decade from 2013 through 2022.

The National Academies 2013 decadal survey, titled Solar and Space Physics: A Science for a Technological Society, made a strong case to recharter the NSWP under the NSTC:

As part of a plan to develop and coordinate a comprehensive program in space weather and climatology, the survey committee recommends that the National Space Weather Program be rechartered under the auspices of the National Science and Technology Council. With the active participation of the Office of Science and Technology Policy and the Office of Management and Budget, the program should build on current agency efforts, leverage the new capabilities and knowledge that will arise from implementation of the programs recommended in this report, and develop additional capabilities, on the ground and in space, that are specifically tailored to space weather monitoring and prediction.

[National Research Council 2013, pp. 8, 111]

With all the mounting evidence of the potential national implications of severe space weather impacts [Holdren and Beddington 2011; National Research Council 2008], congressional direction [GPO 2010], and a long series of recommendations for elevating the U.S. coordination of space weather services, science, preparedness, and response planning to the highest level, the NSTC established the SWORM Task Force in 2014, composed of over 30 different Federal departments, agencies, and offices. The SWORM Task Force sought to meet the objectives of the NASA Authorization Act of 2010 [GPO 2010] to improve the Nation's ability to protect, mitigate, respond to, and recover from the potentially devastating effects of space weather events. The SWORM Task Force released the National Space Weather Strategy and Action Plan (Action Plan) in 2015. Executive Order 13744, Coordinating Efforts to Prepare the Nation for Space Weather Events of 2016 reconstituted the SWORM as a subcommittee to ensure accountability for and coordination of the federal government to implement the Action Plan. The SWORM Subcommittee3 continues to serve as an interagency body that unites the national- and homeland-security enterprise with the science and technology enterprise to define, coordinate, and oversee goals and programmatic authorities of the federal government related to space weather, including research, forecasting, event preparation, mitigation, response, and recovery [NSTC 2015, NSTC 2019].

In 2015, OFCM conducted a thorough mission review of the Federal meteorological coordinating infrastructure. The Federal agencies that participated in this review sent a clear message that OFCM should streamline its coordination infrastructure and that the ICMSSR should absorb the functions of the four OFCM Program Councils and yield the leadership of the NSWP to the newly formed NSTC SWORM Task Force. As a result, the ICMSSR deactivated the NSWP Council on August 10, 2015 [OFCM 2015].

The ICMSSR remained engaged in space weather coordination and conducted complementary space weather activities not managed through the NSTC, such as the annual Space Weather Enterprise Forum. Overall, this evolution and transfer of ICMSSR responsibilities for a national strategy and plan to the NSTC can be viewed as the "coming of age" of the Federal space weather community and its graduation to a new, higher level of executive administration recognition and empowerment.

OFCM continued to provide administrative and logistical support to the SWORM Subcommittee from 2015 through 2021, helping to establish it as an exemplar of interagency efficiency and effectiveness within the NSTC. Among key accomplishments during this period were establishment of an operational suite of space weather models, improved research-to-operations/ operations-to-research capabilities, dedicated space weather ground- and space-based observations, benchmarking of extreme space weather conditions, and substantial improvement in the preparedness of the U.S. electric power distribution grid.

The Federal agencies that established and participated in the NSWP can take credit for a long series of accomplishments facilitated through interagency cooperation. The NSWP partnership improved communication across the federal government and helped foster opportunities in the academic, commercial, and international space weather enterprise. Over its 21-year history, the NSWP was keenly aware of external factors and events regarding space weather and adapted to these new influences accordingly. The program provided a framework for interagency planning and program advancement by the partner agencies [Bonadonna et al. 2016]. As the White House assumed the challenges of leadership of a national program in space weather, this model of successful interagency coordination and planning was applied to the broader Federal Weather Enterprise and incorporated into Section 402 of the Weather Act of 2017 (15 USC 8501), leading to the establishment of ICAMS.

4. Evolution of the National Weather Radar Network

OFCM's involvement with the planning, implementation, and ongoing oversight of the Nation's current weather radar network, NEXRAD (for Next Generation Weather Radar), is documented in *The Federal Role In Meteorological Services And Supporting Research: A Half-Century of Multi-Agency*

[3] For current status, operative documents, and activities, see the SWORM website at https://www.sworm.gov/.

Collaboration [OFCM 2013a, pp. 6-7, 30-34, 39-40]. By 2013 the NEXRAD radars had been operating for two decades, and OFCM interagency groups were involved in exploring prospects for a potential follow-on system based on phased-array radar technology [OFCM 2013a, pp. 63-65]. The NEXRAD radars—as with the legacy system of civilian aircraft surveillance radars—use a single radar beam transmitted from a rotating antenna. In a phased-array radar, the beam emanates from a stationary surface and is shaped and steered electronically, with no rotating antenna. The radar system's electronics can form multiple beams and steer them independently, which means each beam can be used to perform an observing function independent of the other beams. For this reason, civilian applications of phased-array radar are often referred to as multifunction phased-array radar (MPAR).

4.1 OFCM's Role in MPAR Technology Exploration

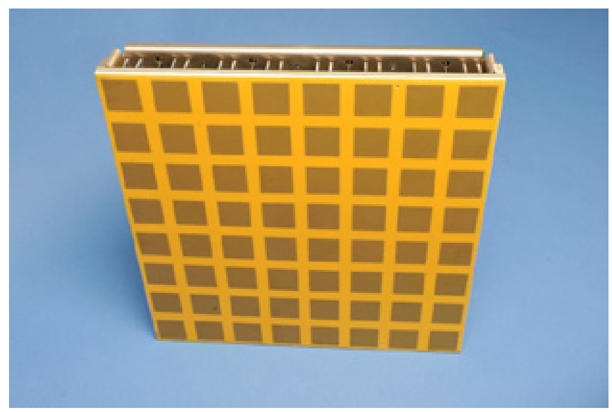
MPAR was an initiative pursued to explore the application of a single phased-array radar system to perform multiple functions (weather surveillance functions and aircraft surveillance functions) currently addressed using individual fleets of specially tailored single-beam radars. The intent was not just to design a radar that agencies could deploy to meet their individual missions, which would save parallel research and development (R&D) investments and reduce costs through larger production runs. An MPAR system would also allow for significant savings by using each installed radar for multiple purposes. For example, one MPAR radar could be used for the National Weather Service's (NWS's) weather surveillance and warning functions; the FAA's air route surveillance and air traffic control; and defense, homeland security, and air traffic control operations of DOD and the Department of Homeland Security (DHS).

In the early 2000s, the National Severe Storms Laboratory (NSSL) established the National Weather Radar Testbed (NWRT) using a military phased-array radar on loan from the Navy. This radar was modified for weather surveillance, and the NWRT quickly proved the value of rapid updates achieved through flexible scanning and began providing key information for advancing the understanding of severe weather. It also prompted the FCMSSR to direct the Federal Coordinator to investigate the possible application of MPAR to the needs of other Federal agencies, particularly the FAA. This led to formation of the MPAR Working Group, which reported to the ICMSSR and was co-chaired by representatives from NOAA, the FAA, the Air Force, and DHS. This working group prepared the report, Federal Research and Development Needs and Priorities for Phased Array Radar [OFCM 2006], and tackled a number of issues related to the challenge of meeting the diverse radar requirements of multiple agencies with a single national system of MPAR radars. The envisioned MPAR system would replace two weather radar systems—the NEXRAD system of WSR-88D weather radars4 and the FAA's Terminal Doppler Weather Radar units—as well as three models of the FAA's terminal air traffic control (ATC) radars (ASR-8, -9, and -11) and four models of the DOD/DHS long-range surveillance radars (ARSR 1 through 4). Additional DOD ATC and long-range surveillance radars (GPN and FPS, respectively) were added later in the program. As the initiative attracted more attention and financial support from the agencies, the FCMSSR established the MPAR Executive Council to provide senior oversight to the working group.

[4] "WSR-88D" is the abbreviation for "Weather Service Radar 1988 Doppler."

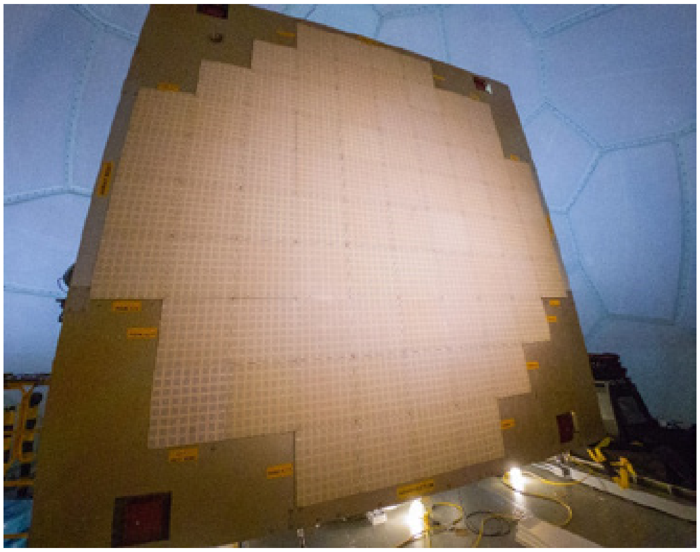
To address the challenge of developing the dual-polarized phased-array technology required for weather observations, the MPAR Working Group facilitated FAA and NOAA efforts to design and build a series of flat panels with 64 small dual-polarized antennas—essentially the building blocks of a full-scale MPAR antenna. Each subsequent panel built on and improved the technology of the earlier panels in the series until a technology was achieved that was deemed feasible in cost and functionality for application in a full-scale antenna.

In 2012 work began on building a small dual-polarized phased-array radar unit applying this technology. This prototype unit was assembled in a 2-by-5 array of 10 panels and mounted on a trailer for transportability. Development and assembly of the prototype provided the opportunity to address the challenges of mounting the panels adjacent to each other and connecting power, signal, and other functions to each panel. It also allowed the integration of a "back end" that would design and coordinate the phased transmissions from the 640 individual elements on the face of the radar and collect and form beams from the returned signals. The prototype, assembled at MIT Lincoln Labs, made its debut at NSSL in the spring of 2015 and helped identify and address issues related to assembly, maintenance, operation, and signal and data processing.



A 64-element array panels for use in an MPAR antenna. Photo courtesy MIT Lincoln Laboratory.

Based on this progress with a suitable MPAR technology, NOAA and the FAA initiated plans to build a full-scale radar, called the Advanced Technology Demonstrator (ATD), to replace the Navy-loaned unit at the NWRT. The ATD antenna would comprise 76 of the 64-element panels, assembled into a 14-by-14-foot array. To reduce development time, an existing backend based on the Affordable Common Radar Architecture under development at the Office of Naval Research was modified and adapted to the antenna. After further construction, testing, and installation work, the ATD was ready for integration and functional testing in the summer of 2018. Although the first weather images were recorded the following spring, full integration and testing of the ADT focused on evaluating and calibrating the dual-polarization capability, which took nearly 3 years. Initial Operating Capability was declared in April of 2021, and the system began use as a meteorological and engineering research testbed.



The fully assembled ATD antenna, installed inside the weather radar radome at NSSL.

In 2015 Congress passed the Spectrum Pipeline Act (Public Law 114-74; 47 U.S.C. 923, 928), which required the Federal Communications Commission to auction off, by 2024, part of the radio-frequency spectrum used by Federal agencies. The act also directed the National Telecommunications and Information Administration, the body responsible for managing radio-frequency spectrum use by Federal agencies, to make funds available from the Spectrum Relocation Fund "to pay Federal entities for research and development activities to improve the efficiency and effectiveness of their spectrum use in order to make additional frequencies available for auction." The FAA and NOAA made use of this provision to acquire additional funding for the ATD.

In 2016 the four MPAR agencies, taking advantage of the same provision, signed a memorandum of understanding establishing a program to pursue research and development targeting the deployment of a radar system in time to support the 2024 spectrum auction.

An interagency program office was established within the FAA to manage the new R&D program, which was named SENSR, for Spectrum Efficient National Surveillance Radar. In addition to transitioning a concept development initiative into a targeted R&D program, the move from MPAR to SENSR changed the dynamics of interagency involvement. DOD and DHS, which had been involved in MPAR as observers and advisors, were now active participants in what would become an operational program. At the same time, NOAA's involvement shifted from a research initiative within the Office of Oceanic and Atmospheric Research to an operational radar replacement program within the NWS. MPAR as an initiative coordinated through the OFCM structure ended in 2016, although OFCM continued to support SENSR on an advisory basis at the request of the FAA program office.

Ultimately, due to technical challenges and tight timelines, the SENSR program did not reach fruition. In 2019 NOAA responded to congressional concerns about the future of weather radar with a weather radar follow-on plan, which laid out the options for future national weather radar and the process for investigating and deciding on the best option (NOAA 2019). One of the options detailed in the report was a phased-array radar based on MPAR weather concepts and ATD technologies. According to the report, the ATD, "a foundational asset for NOAA's planned acquisition risk reduction program," will play a key role in determining whether a dual-polarization phased-array radar will be deployed operationally as the next NWS weather radar platform.

Thus, the ATD—the culmination of the two-decade-long MPAR initiative—will serve two key functions in the coming years. First, it will provide storm data necessary for advancing the understanding of severe storms and how to forecast them. Second, it will provide information to support key decisions about the next national weather radar system, which will provide data critical to the protection of life and property for decades to come.

4.2 OFCM Involvement with the Wind Turbine Radar Interference Mitigation Working Group

The proliferation of wind turbine farms for the generation of electricity began creating concerns about interference with radar systems as early as 2006. The problem affected both air surveillance and weather radars, causing significant impacts to the detection of aircraft and hazardous weather. Because the MPAR agile-beam concept showed a potential for reducing wind turbine interference, DoD contacted OFCM to learn more. Over time, a group of interested agencies came together to study the nature of radar interference from wind turbines and to strategize ways to deal with it. OFCM helped to coordinate this work, which eventually resulted in a 2014 memorandum of understanding that established the Wind Turbine Interference Mitigation Working Group.5 This working group was not a part of the OFCM coordinating infrastructure, but OFCM served as the NOAA point of contact for it and helped coordinate the development of the Federal Interagency Wind Turbine Radar Interference Mitigation Strategy,6 published in January 2016. NOAA's Radar Operation Center now serves as the NOAA point of contact.

4.3 Review of ITAR for Concerns with Documenting Civilian Use of Phased-Array Radar

The International Trade in Arms Regulations (ITAR) restrict the open publication of information about technologies that may be of military importance, whether or not such information has been formally classified. In August 2013 the Assistant Secretary of Commerce for Export Administration requested that OFCM coordinate a review of changes to ITAR by Federal agencies involved in the development of radar systems for civilian use. A key concern was that without such changes, ITAR would prohibit open discussion and documentation of radar technologies (such as phased-array radar) that, although initially developed for military use, were now important to civilian applications. The section under review was the U.S. Munitions List Category IX–Military Electronics.

OFCM reviewed the ITAR section of interest and highlighted areas of concern with respect to the ongoing work on MPAR. Then, using the MPAR Working Group contacts and infrastructure, OFCM provided its analysis to the affected Federal agencies and gathered their comments. In December 2013 OFCM provided consolidated comments to the Assistant Secretary.

Separate from OFCM, the FAA and NSSL responded directly to the Assistant Secretary, articulating with additional detail their particular concerns. In January 2014 MPAR Working Group representatives from the FAA and OFCM (representing the other MPAR agencies) met with the Assistant Secretary and his DOD and State Department counterparts to discuss the Federal agency response, answer staff questions, and articulate the concerns arising from the new version of the regulation. Although not all these concerns were alleviated by revisions to ITAR, the interaction between the radar-involved agencies and those rewriting the regulation resulted in useful changes

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[5] The memorandum of understanding is available online at: https://www.acq.osd.mil/DODsc/library/15-S-1452%20WTRIM%20MOU.pdf.

[6] The strategy document is available online at: https://www.energy.gov/sites/default/files/2016/06/f32/Federal-Interagency-Wind-Turbine-Radar-Interference-Mitigation-Strategy-02092016rev.pdf.

that eliminated unnecessary restrictions on the export of (and open-source publication about) civilian applications of radar-related technology.

5. Tropical Cyclone Operations and Research

As in the past, OFCM support to tropical cyclone observing and forecasting operations during 2014–2021 continued to focus on convening the community annually at the Interdepartmental Hurricane Conference (IHC) and the coordination of annual changes to and publication of the National Hurricane Operations Plan. OFCM support to tropical cyclone research was driven by the Interagency Strategic Research Plan for Tropical Cyclones [OFCM 2007]. The strategic plan was developed by the OFCM-sponsored Joint Action Group for Tropical Cyclone Research and published in 2007. To coordinate the response to the plan, the JAG was reconstituted as an OFCM working group, which met over the years after 2007 to track progress and adjust priorities.

As the midpoint of the decade-long research effort driven by the plan approached, OFCM's work in this area evolved to focus more on interagency coordination of tropical cyclone research. In 2013 the IHC was renamed the Interdepartmental Hurricane Conference–Tropical Cyclone Research Forum (IHC-TCRF), reflecting the increasing emphasis on research that had emerged in recent IHCs. The work of NOAA's Hurricane Forecast Improvement Program, as well as tropical cyclone–relevant research sponsored by NASA and NSF, were highlighted, as was the status of research-to-operations projects at the Joint Hurricane Testbed. The focus on research peaked in 2014 and 2015, when the annual meetings were called the TCRF-IHC and most of the agenda addressed the research programs of participating agencies.

By 2015 the acting Federal Coordinator recognized that the end of the decade-long research effort proposed in the 2007 strategic plan was approaching. Furthermore, much of the proposed research had been completed, and results were being transitioned into operations. During the 2015 TCRF-IHC, he led a session in which the agency participants were asked for their perspectives on the future of the IHC. The responses showed strong support for enhancing the interaction between the operations and research communities and for returning the venue for the IHC to south Florida, to facilitate participation by a critical mass from both of these communities.

In 2016 the word "Operations" was added to the title of the forum (Tropical Cyclone Operations and Research Forum, TCORF), which was held in the Miami area and planned to deepen the involvement of the National Hurricane Center. This approach worked well and was used for planning and conducting TCORF-IHCs in subsequent years. Agendas for those gatherings reinstated reviews of the previous tropical cyclone season and planning of operations for the upcoming season. These forums also included sessions for robust exchange among participants on priorities and progress related to important aspects of tropical storm observing, modeling, and forecasting and to the research supporting the advancement of these operational elements.

As the focus and the agenda evolved during these eight years, the annual forum played an important role in engaging a diverse group of interagency experts to help advance the research laid out in the 2007 strategic plan. They also provided opportunities for the broader tropical cyclone observing and forecasting community to stay informed about research efforts such as the Hurricane Forecast Improvement Program, and about the transition of research results into operations via the Joint Hurricane Testbed.

OFCM's support to the tropical cyclone community during this period contributed to significant improvements in forecasting capability. From the strategic research plan to the working group activities to the annual research forums, OFCM played a key role in helping the agencies work together to address the challenges of improving observing, modeling, and forecasting. The result was more-accurate forecast tracks and hurricane intensities, ultimately leading to more timely and effective warnings, better preparedness, and lives saved.

6. Work of the Committee for Operational Processing Centers

For decades, OFCM's Committee for Operational Processing Centers (COPC) served as the interagency body for coordinating the operational and R&D activities of the Nation's civilian and military meteorological operational processing centers (OPCs). These centers are responsible for numerical weather prediction (NWP) modeling, data assimilation into NWP models, and production of analysis and forecast products and services that depend on both atmospheric and coupled air-land-ocean modeling [OFCM 2013a, pp. 17-18, 62-63]. COPC supported the work of the OPCs by providing an interagency forum to discuss and improve exchange of observational data, leverage global observing capabilities, and increase the resilience of Federal forecasting processes by strengthening interoperability among forecasting centers. COPC and the working groups that reported to it—Cooperative Support and Backup (WG/CSAB), Centralized Communications Management (WG/CCM), and Observational Data (WG/OD)—provided forums for issue discovery and for interagency cooperation and coordination aimed at sharing efficiencies and leveraging joint exploitation of agencies' capabilities.

During 2014–2021 COPC activity included the creation of procedures for working with new observational and communications capabilities and for the transition to new international data management standards and procedures initiated by the WMO and the International Civil Aviation Organization (ICAO). This legacy work of COPC and its working groups continues under ICAMS, where COPC is now the Subcommittee for Operational Processing Centers under the ICAMS Committee on Cyber, Facilities and Infrastructure.

To deal with ongoing challenges and to plan for foreseeable data management challenges, an inaugural observational data workshop was held under COPC auspices in the fall of 2011, followed by a second workshop in 2018 [OFCM 2012, OFCM 2018b]. As new observational and communications capabilities (satellite-based and conventional) were fielded—and in response to key takeaways from the observational data workshops—COPC and its subordinate working groups created and implemented the initiatives discussed below.

New WMO and ICAO coding standards and data management procedures required interagency collaboration to develop guidance and procedures for U.S. Federal agencies and their state, local, academic, and private-sector partners in the following areas:

- ***WMO migration from Traditional Alphanumeric Code (TAC) forms to Binary Universal Form for the Representation of meteorological information (BUFR).*** Although the WMO plans to replace all use of TAC-formatted messages on its Global Telecommunication System (GTS) with BUFR formats, replacement BUFR products are not yet available for all message types. Also, some WMO Member nations continue to use TAC for all their data reported on GTS. The U.S. OPCs thus had to develop capability to receive and process both TAC and BUFR products during an extended transition period. The WG/OD kept abreast of this fluid situation, enabling discussion of WMO actions and guidance among the OPC representatives on the working group and communicating WMO plans and regulations through a new Federal Meteorological Handbook (FMH), U.S. Federal Meteorological Data Management Practices: A Guide to Standards and Best Practices. FMH-13 [OFCM 2020, ICAMS 2021].

- ***Migration of U.S. radiosonde data from TAC forms to high-resolution BUFR.*** This transition initially resulted in numerous metadata errors, first noticed by the U.S. Air Force's 557th Weather Wing. Following a collaborative study by WG/OD members into the causes and possible solutions, a project was undertaken by the NWS to obtain access in real time to the raw, high-resolution radiosonde data from NWS Weather Forecast Offices and convert it directly into WMO-approved BUFR code for dissemination worldwide via the GTS. This direct conversion eliminates errors introduced by less-direct conversion processes. Other initiatives started by the WG/OD to address radiosonde data quality include:
    - Routine reporting and comparison, during weekly WG/OD meetings, of data and metadata error discoveries, with follow-up actions taken to find solutions and track progress to final fix
    - Consulting with data program managers (e.g., NWS manager for upper-air observations) to pinpoint problems and find solutions
    - Finding appropriate U.S. and WMO points of contact to address and fix specific data issues, including both U.S. and non-U.S. sources of such data.
    - Requested and obtained inclusion of a U.S. OPC representative on the WMO Task Team for Upper Air Transition to BUFR
    - Participated in the Operational Test and Evaluation of the NWS Replacement Radiosonde System (RRS) and then the successor system to RRS for manually launched NWS radiosondes, the Manual Radiosonde Observing System (MROS).

- ***Implementation of the new WMO Integrated Global Observing System (WIGOS) framework and its Observing Systems Capability Analysis and Review tool for surface (non-satellite) observing platforms (OSCAR/Surface)***. OSCAR/Surface is the WMO's new official repository for observing platform metadata. The transition from the WMO's legacy metadata document to this new database repository began in 2016, and the WIGOS Initial Operational Phase began on 1 January 2020. The WG/OD developed procedures and guidance for U.S. users of the WIGOS-era GTS and published them in FMH-13. This guidance includes a plan for assigning a U.S. Focal Point for OSCAR/Surface metadata correction and maintenance within each Federal agency with observing-platform reporting responsibilities. These agency Focal Points are also responsible for assigning WIGOS station identifiers (WSIs) to new observing platforms managed or overseen by their agency [OFCM 2020, ICAMS 2021].

    - ***Transition from Legacy Observing Station Identifiers to WSIs.*** The WMO has specified a format for WSIs that is much more complex than the observing-station identifiers previously used in GTS messages. The U.S. OPCs and other users of GTS data must therefore account for this new identifier structure when decoding GTS messages. The WG/OD provided guidance on how to interpret WSI formatting in FMH-13 [OFCM 2020, ICAMS 2021]. To ensure U.S. representation in the WIGOS transition, a WG/OD member from the U.S. Navy was assigned to the WMO Task Team for WSIs.

The WG/OD also compiled best practices in quality control and issued U.S. guidance for new international data management standards in the following areas:

- Implementation of a cross-OPC consolidated quality control process for discovery and reporting of metadata errors, followed by tracking error correction to final fix.
- The second release of FMH-13, in December 2021, added guidance for U.S. users on migration of aviation weather reports from legacy formats to the new ICAO standard, IWXXM [ICAMS 2021, Part 3].

COPC's Working Group for Cooperative Support and Backup coordinated and documented the agreement among the national OPCs for cooperative support and outage mitigation requirements related to data collection and processing (the data inputs to the OPCs) and to developing and disseminating meteorological, oceanographic, and satellite products (OPC outputs).

- WG/CSAB reviewed and updated the *Federal Plan for Cooperative Support and Outage Mitigation Among Operational Processing Centers* [OFCM 2018a].
- WG/CSAB supported the transition by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) from its legacy Data Acquisition, Processing, and Exchange (DAPE) Gateway to the new NESDIS Product Distribution and Access (PDA) enterprise capability. Specifically, the working group facilitated interagency briefings and sharing of questions, comments, and concerns of the user-agencies related to risk, latency, and other aspects of the change in transmission pathway.
- WG/CSAB developed alternative ways for DOD to acquire Geostationary Operational Environmental Satellite (GOES) data, in order to alleviate the load on the NESDIS PDA.
- WG/CSAB coordinated participation of the OPCs within DOD (Navy and Air Force) in the Global Data Exchange for NWP.
- WG/CSAB and WG/OD arranged for regular update briefings at COPC meetings from the Joint Center for Satellite Data Assimilation, to ensure not only that satellite data streams are available to all parties but also that methods to enable and improve assimilation of those data in operational environmental prediction modeling and forecasts systems are developed and shared efficiently and effectively.

Two COPC working groups, WG/CSAB and the satellite data subgroup of WG/OD, worked together to facilitate the acquisition, processing, exchange, and management of satellite observational data among the OPCs. During 2014–2021, they accomplished the following:

- Coordinated efforts to make the Himawari data available to all the OPCs.
- Assisted the OPCs' use of the new NESDIS secure data ingest system for mitigating information assurance and cybersecurity risk when data are received from outside the agency data providers to address global refresh requirements that depend on foreign data sources.
- Monitored and coordinated all actions leading to the potential removal of DOMSAT as a delivery vehicle for EUMETSAT data, replacing it with a data feed to DOD OPCs via the NESDIS PDA.
- Coordinated the OPCs transition to GOES-16/17.
- Monitored the DOD's modification and installment of antennas to receive GOES Rebroadcast.

- Shared information on potential future OPC/COPC satellite data changes and their impacts on the OPCs.

The COPC Working group for Centralized Communications Management monitors the effectiveness of communications between the national OPCs and works with the OPCs on capacity planning and forward projection of capability needs. During the 2014–2021 period, WG/CCM facilitated monthly and semiannual interagency discussions on OPC data exchange and processing issues, including infrastructure changes that could potentially interfere with interoperability among the nation's OPCs. This working group was also active in the following areas:

- Coordinated communications issues between the OPCs related to data from ocean-based observing platforms.
- Developed a second (alternative) pathway for data communications from NESDIS and the NWS's National Centers for Environmental Prediction to the three DOD OPC sites: the Air Force 557th Weather Wing, the Naval Oceanographic Office, and the Navy's Fleet Numerical Meteorology and Oceanography Center. This alternative communications pathway connects through NOAA/Boulder in Colorado and nearby Buckley Air Force Base in Aurora, Colorado. This effort included implementing an automatic switch-over to the alternative path if the primary path fails.
- Coordinated and implemented a data exchange mechanism to fully utilize both NWS Integrated Dissemination Program locations (College Park, MD, and Boulder, CO).
- Established new dark-fiber connections between the NOAA/NESDIS Satellite Operations Facility in Hillcrest Heights, MD, and DOD's National Maritime Intelligence Center in nearby Suitland, MD.
- Developed a template for the OPCs to catalog data exchanges and estimate future bandwidth requirements.
- Performed data latency testing for the Joint Region Security Stack (JRSS) between OPCs.
- Investigated and developed potential concepts of action for exchanging data between NESDIS and the Air Force OPC via the digital cloud, in light of concerns about data access, cyber security, and latency.

7. Other Areas of OFCM Coordination, 2014–2021

7.1 Disaster Impact Assessments and the COASTAL Act of 2012

OFCM created a working group in the 1990s to plan and coordinate interagency activities for acquiring scientific and engineering data on storm damage and related effects, referred to as "post-storm impact assessment." These assessments focused on collecting highly perishable data before it disappeared [OFCM 2013a, pp. 18–19]. In 2010, OFCM established the Working Group for Disaster Impact Assessments and Plans: Weather and Water Data (WG/DIAP) to extend this legacy work on post-storm impact assessments to a broader range of weather-related disasters. The WG/DIAP developed a National Plan for Disaster Impact Assessments: Weather and Water Data (NPDIA). The plan addressed new methods and procedures for: (1) pre-deploying, increasing the density of, and hardening systems for taking observations during and immediately after a major storm event; and (2) collecting and disseminating real-time data of value for forecasting these storm events and for managing Federal, State, and local response and recovery activities [OFCM 2017b].

The success of these expanded capabilities and storm assessment procedures was a key factor in Congress's deliberations on and formulation of the Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act of 2012 [GPO 2012]. The intent of the COASTAL Act was to help lower costs incurred by the National Flood Insurance Program by providing an objective and rigorous system for discerning wind damage versus storm-surge damage in cases of property losses due to land-falling hurricanes or tropical storms. OFCM was charged with coordinating interagency efforts to establish capabilities to meet the requirements mandated by the COASTAL Act of 2012.

In response to the statutory mandate, OFCM established the Joint Action Group for COASTAL Act Post-Storm Analysis in 2013 to produce a COASTAL Act Capabilities Development Plan (CACDP) that would:

- Establish a COASTAL Act Named Storm data collection policy,
- Initiate program development of a COASTAL Wind and Water Events Database and the Named Storm Event Model (NSEM), and
- Develop the COASTAL Formula for indeterminate losses.

The mandate also called for the development of a data collection protocol for the coordinated deployment of mobile observation platforms to intercept land-falling, COASTAL Act-designated storms, thereby increasing the density of storm data collected for these storms. Following data collection protocols of the NPDIA, OFCM coordinated deployment of mobile observing and post-storm assessment teams, including teams consisting of WG/DIAP-member and government- and university-based technical experts, during each hurricane season from 2014 through 2021. Strategically placed observing assets, along with post-storm impact assessments, provided critical real-time and post-storm data along the path of the most severe land-falling hurricanes during this period, including historical storms such as Hurricane Harvey in 2017—one of the costliest on record.

Following the CACDP, and with support from the COASTAL Act, NOAA successfully secured budgetary support in 2015 to develop a new COASTAL Act post-storm analysis capability. Starting in 2020, this new analysis capability has been used to produce post-storm analyses.

7.2 A New Way to Report on the Federal Weather Enterprise

In early 2016, OFCM began a reassessment of the annual Federal Plan for Meteorological Services and Supporting Research (hereafter, "Federal Plan"). This document had been produced annually since 1964 as a response to Public Law 87-843, enacted in 1963, which directed the Bureau of the Budget (the predecessor to OMB) to provide Congress with "a horizontal budget showing the totality of the programs for meteorology, the specific aspects of the program and funding assigned to each agency, and the estimated goals and financial requirements." In 1964, there were six Federal agencies with meteorology-related programs. NOAA was not among them, as that agency had not yet been created, and the Federal Plan was a fairly compact document of about 35 pages. By 2016, the Federal Weather Enterprise consisted of fifteen cabinet- and service-level agencies: Department of Commerce (NOAA, represented by the NWS, Office of Atmospheric Research, and NESDIS), DOD (Army, Navy-Marine Corps, Air Force-Space Force), DHS (Federal Emergency Management Agency, Coast Guard), Department of Energy, Department of the Interior (U.S. Geological Survey), Department of Transportation (the FAA and the Federal Highway Administration), NASA, Nuclear Regulatory Commission, Department of Agriculture, Environmental Protection Agency, National

Transportation Safety Board, National Science Foundation, and OSTP. The annual Federal Plan had grown to a 200-plus page collection of discrete program status reports and goal statements from each agency, preceded by a section of agency-specific budget reports that were duplicative of other government-mandated statements.

The OFCM working group that was formed to develop a revised Federal Plan format realized that a concise but useful document should both report on the activities and budget transfers of each agency and document progress on coordinated Federal goals for meteorological services and the research to improve those services. However, there was no document (other than the collective minutes of FCMSSR and ICMSSR meetings) that described the coordinated objectives of the Federal Weather Enterprise. Thus, OFCM began drafting a Strategic Plan for Federal Weather Enterprise Coordination, with the intent that this would be a high-level document with 5 to 7 overarching strategic goals for the Enterprise, to be reviewed and updated every 4 to 5 years [OFCM 2017c]. The annual replacement for the legacy Federal Plan would describe annual efforts that furthered these goals.

The working group endeavored to transform a static overview of agency accomplishments and activities into a tool that provided feedback to Federal budget managers and Congress on how the funds appropriated for meteorology were being used. Additionally, the working group wanted to create a tool that encouraged and reported on coordination among the agencies, which each have unique needs and are mission-funded for widely varying levels of effort in meteorological issues.

The result was a Budget and Coordination Report in two sections [OFCM 2017d].

7.3 OFCM Partnership with the National Earth System Prediction Capability

The National Unified Operational Prediction Capability (NUOPC) and its follow-on, the National Earth System Prediction Capability, grew out of the regular interactions between the NOAA Administrator, the head of Air Force Weather, and the Oceanographer of the Navy. From these regular meetings, they felt they could work more closely for a national prediction/forecasting capability through a multi-agency, model-model ensemble. This concept was discussed at meetings in 2005 and led in 2007 to an in-depth study to find an approach. By 2009, the NUOPC was staffed and working as an interagency partnership to achieve a new capability for improved prediction.

In 2011 the NUOPC ensemble went operational with a 16-day forecast from three separate models. Leveraging the North American Ensemble Forecast System—an agreement between the United States, Mexico, and Canada that brought together the NOAA ensemble and Canadian ensemble to make a common forecast product—NUOPC added the U.S. Navy ensemble, while the U.S. Air Force added new post-processing. The new capability went operational in 2011 with each of three modeling centers providing 20 modeling outputs (members), for a combined 63-member ensemble capable of producing 16-day forecasts. The product from this new capability showed forecast skill7 out to day nine.

[7] In weather forecasting, "skill" is a measure of the improved accuracy of a forecast compared with a simple historical baseline of past observations. A skill measure may use a single metric or multiple metrics.

NUOPC continued to grow and mature; in 2012 the need was recognized to better engage the science agencies to support continued development of this partnership. In response, the Earth System Prediction Capability (ESPC) was started, with the challenge to provide forecast capabilities for periods from time zero ("nowcasts") out to 30 years. In 2014 these two efforts, NUOPC and ESPC, were brought together under one charter as the National ESPC with the goal of a fully coupled Earth System Modeling Ensemble System capable of providing forecasts across time scales.

The connection with OFCM grew during this period, as it was clear that OFCM's COPC was the key stakeholder in operating and maintaining the operational ensemble created under NUOPC and now continuing as the National ESPC. At a FCMSSR meeting in 2015, the National ESPC leadership discussed the need for better connection of their effort to the top levels of the Federal Weather Enterprise agencies, in order to foster support for and improve understanding of the needs of the effort. In 2016 the National ESPC was incorporated into the OFCM coordination structure as a group reporting directly to the FCMSSR [OFCM 2016].

7.4 Interagency Coordination for Expanded Applications of Unmanned Automated Systems for Weather and Earth System Observations

OFCM engagement in interagency coordination of unmanned automated systems (UASs) began in 2011 in response to a request from the NOAA Unmanned Systems Office and the Department of Energy's Office of Science to assist the Federal Weather Enterprise in finding ways to better plan for and use UASs for environmental monitoring applications. OFCM joined the Interagency Coordinating Committee for Airborne Geophysical Research Aircraft and the NSTC Task Force on Unmanned Systems to provide a cross-agency perspective on ongoing efforts. The OFCM conducted an exploratory workshop in February 2011, resulting in recommendations documented in the report, Utilization of Unmanned Aircraft Systems for Environmental Monitoring Exploratory Mini-Workshop Summary Report [OFCM 2011]. To follow up on these recommendations, OFCM established the Joint Action Group for Unmanned Aerial Systems in 2012. Efforts of this JAG resulted in better coordination between NOAA, NASA, the FAA, the US. Department of Energy, and other agencies with emerging UAS capabilities for airborne weather and Earth system observations. Among the significant results were annual joint-agency field research campaigns, NOAA's Sensing Hazards with Operational Unmanned Technology (SHOUT) program, and aerial deployment of UASs from NOAA and Air Force reconnaissance aircraft between 2015 and 2021.

7.5 Interagency Coordination on Environmental Satellite Issues and Initiatives

Throughout its first half-century, OFCM was active in coordinating interagency issues involving meteorological and other Earth-observing satellites [OFCM 2013a]. This coordination role continued in 2014, when the Oceanographer of the Navy asked OFCM to re-establish the Committee for Operational Environmental Satellite Systems (COES) to provide Federal interagency coordination of environmental satellite issues and initiatives. During the period from 2014 through 2021, COES was active in the following important areas, which are discussed further below:

- Coordination of NOAA and DOD plans to mitigate the loss of expected observing capabilities previously provided by the National Polar-orbiting Operational Environmental Satellite System (NPOESS)
- Early discussions of interagency cooperation to provide DOD with geosynchronous satellite coverage of the Indian Ocean

- Initiation of plans to mitigate radio frequency interference (RFI) with satellite sensing and communications
- Interagency collaboration on emerging commercial sources of space-based atmospheric and space weather data

Following the termination of NPOESS in 2010, NOAA and DOD were directed by Congress to develop continuity and advancement of space-based environmental monitoring (SBEM) capabilities separately. NOAA was able to work with NASA to complete development of the NPOESS Preparatory Program (NPP) spacecraft and begin the new Joint Polar Satellite System. Meanwhile, DOD had to initiate a new SBEM program and deliver required capabilities by the end of life for the Defense Meteorological Satellite Program on-orbit systems. Recognizing the need for interagency coordination and partnership, NOAA and DOD used the newly re-established COES as a primary channel of communication and cooperation.

In 2015, COES identified and corrected a serious lack of interagency coordination of environmental satellite coverage over the Indian Ocean. In response, NOAA and DOD initiated plans to employ residual NOAA GOES satellites and DOD ground facilities to cover the Indian Ocean area. COES also assisted the U.S. delegation to the annual WMO Coordinating Group on Meteorological Satellites by providing support for a unified position supporting the international plan to provide Indian Ocean weather surveillance for the next decade.

As industry began developing systems for 5G cellular communication, technical studies conducted by NOAA identified potential RFI from 5G transmissions with the communications downlinks from its new multibillion-dollar GOES R-Series satellite systems. NOAA members briefed COES to build interagency consensus and support for mitigation actions and capabilities. The RFI problem posed threats to the primary mission data downlink, the remote Data Collection System and microwave-sensing capabilities from low Earth-orbit. OFCM took the issue as formulated by COES and raised it first to the ICMSSR and eventually to the FCMSSR. Although the issue was raised to the Federal Communications Commission and the White House, no relief from the commercial-sector RFI could be negotiated. However, NOAA was able to secure funding for internal actions to ameliorate the impact.

Also in 2016, NOAA briefed COES on its Commercial Weather Data Pilot Program. During the meeting, the committee discovered that similar activities were ongoing in NASA and the Air Force. These initiatives became a regular topic for discussion at COES meetings and eventually led to formation of the Working Group on Interagency Coordination of Commercial Weather Data (WG/ICCWD). The WG/ICCWD produced an interagency white paper on best practices for commercial weather data among the Federal agencies. This white paper was shared with the Commercial Data Team of NSTC's U.S. Group on Earth Observations and provided the basis for White House policy on the issue. Congressional authorization and appropriations for government acquisition of commercial weather data were eventually included in the Weather of Act of 2017 and in the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act of 2020 [GPO 2020]. As of 2021, it is anticipated that various sources of commercial weather data from satellites and other platforms will be an indispensable component of the global Earth observing system.

7.6 Operational Planning for the Winter Storm Season

During 2014–2021 OFCM continued to edit and publish the annual National Winter Season Operations Plan. This plan focuses on coordinating requirements for the coming winter season's reconnaissance observations, which are provided by the Air Force Reserve Command's 53rd Weather Reconnaissance Squadron and NOAA's Aircraft Operations Center. Formerly called the National Winter Storm Operations Plan, the document had traditionally addressed aerial reconnaissance of cyclonic storms off the Pacific Coast, where in situ observations were limited, and off the East Coast, where winter-season "bomb cyclones"8 threatened population centers along the Atlantic seaboard and throughout New England. In the early 2010s, questions about the value of aircraft observations of storms in the Pacific resulted in a reduction in that support, although East Coast reconnaissance continued. With the recognition of the importance of atmospheric rivers and the potential impact they have in terms of heavy rain and snow in Pacific coastal states, interest in observations from aircraft returned. Recent studies (e.g., Tallapragada et al. 2022) have confirmed the usefulness of aerial reconnaissance in forecasting extreme precipitation caused by atmospheric rivers. These studies validate the importance of OFCM's role in coordinating the planning for winter season observing campaigns and publishing an annual plan that documents agencies' roles in gathering aerial weather observations, which can be crucial to understanding and forecasting the heavy precipitation caused by winter-season storms.

7.7 Updates to Federal Meteorological Handbooks

OFCM assumed responsibility for maintaining the Federal Meteorological Handbooks (FMHs) from the NWS in 1980. At that time the handbooks documented weather observing and reporting practices for surface, upper air, weather radar, and meteorological rocket observations. Over the years, as needs and technology evolved, some handbooks were deemed unnecessary and discontinued (e.g., barometry, rocket observations) while others were added (e.g., meteorological codes and coding practices). Updating the handbooks involves meticulous drafting and coordination of text with interested agencies. The following handbooks were updated or newly issued between 2014 and December 2021:

- FMH-1, *Surface Weather Observations and Reports*. November 2017; July 2019
- FMH-11, *Doppler Radar Meteorological Observations* (WSR-88D):
  - Part A, System Concepts, Responsibilities and Procedures. January 2016; July 2021
  - Part C, WSR-88D Products and Algorithms. October 2017
- FMH-12, *United States Meteorological Codes and Coding Practices*, Change 4. October 2019
- FMH-13, *U.S. Federal Meteorological Data Management Handbook: A Guide to Standards and Best Practices*: Release 1, June 2020 [OFCM 2020]; Release 2, December 2021 [ICAMS 2021].

[8] What is known as a bomb cyclone occurs through a process, called "bombogenesis," in which a mid-latitude cyclone rapidly intensifies, dropping at least 24 millibars over 24 hours. Bombogenesis can happen when a cold air mass collides with a warm air mass, such as air over warm ocean waters. The resulting rapidly strengthening weather system is popularly called a "bomb cyclone" [NOAA 2022].

8. Conclusion

At the direction of the OSTP Director in response to the congressional mandate in the Weather Act of 2017, OFCM was succeeded by IMCO in December 2021. For 57 years, OFCM provided a unique and critical function to the U.S. government and the people of our Nation. This report documents the final chapter of OFCM's history. This report and the OFCM "Half-Century" report published in 2013 [OFCM 2013a] together summarize the complete history of this small but influential organization.

The many accomplishments fostered by OFCM and well documented in these two reports include the following highlights:

- Seamless integration and daily coordination of five meteorological and oceanographic Operational Processing Centers (OPCs) from two Federal Departments provides round-the-clock ("24/7") environmental services spanning the globe.
- OFCM played a crucial part in planning and implementation oversight for the NEXRAD WSR-88D Doppler weather radar network, a program that was conducted jointly under three Federal cabinet departments and resulted in the nationwide integrated system that continues to provide real-time data for life-saving warnings and advisories, as well as the data foundation for national, regional, and county-level weather forecasting.
- Coordination of aerial reconnaissance assets from NOAA and DOD provide critical observations of tropical cyclones and devastating land-falling hurricanes.
- OFCM committees and working groups coordinated and fostered countless improvements—by all participants in the Federal Weather Enterprise—to aviation, maritime, and road transportation weather services and improvements to Earth-system observation and forecast capabilities.
- Our understanding of Space Weather advanced from a poorly-understood curiosity, to understanding the national existential threats posed from Space Weather events. This new understanding has led to the deployment of advanced space weather observing systems, prediction models, and modernization of the Nation's electrical power grid. .

From this complete historical record, one can see the ebb and flow of coordination philosophy through the years. At first, OFCM was established under an authoritative Federal Coordinator with great influence over the Federal Weather Enterprise. This evolved to a more supporting role, as the OFCM was relegated to a lower level within NOAA. Following GAO recommendations in 1980, OFCM was revitalized and the FCMSSR played an influential role in guiding and providing the authority for OFCM coordinating activities. In the early 2000s, the FCMSSR became idle and the Federal Coordinator rose to be the leading voice for interagency meteorological coordination. In its final years, the FCMSSR again became active and the Federal Coordinator played a strong supporting role. In each period, OFCM always served the Nation as the focal point for coordinating Federal meteorological services and found ways to inspire, foster, and support advancement of those services and of the research essential to improving them to meet evolving and expanding National needs.

OFCM was described as the "United Nations" of the Federal meteorological community. It was a place where all voices were heard, current and future plans were discussed, and actions were planned and taken. The Nation benefited from the resulting cooperation among Federal agencies, academic consultants, and commercial partners to advance meteorological services and research.

It was with great pride of accomplishment and integrity of service that OFCM passed the baton to the new ICAMS and IMCO, in fulfillment of the law and for the continued advancement of the Federal meteorological enterprise.

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Appendix 1
Acronyms

ACE	Advanced Composition Explorer [NASA spacecraft]
ATC	Air traffic control
ATD	Advanced Technology Demonstrator
BUFR	Binary Universal Form for the Representation of meteorological information
CACDP	COASTAL Act Capabilities Development Plan
COASTAL	Consumer Option for an Alternative System to Allocate Losses [Act]
COES	[OFCM] Committee for Operational Environmental Satellite Systems
COPC	[OFCM] Committee for Operational Processing Centers
COSMIC-2	Constellation Observing System for Meteorology, Ionosphere, and Climate–2
DAPE	Data Acquisition, Processing, and Exchange
DOD	U.S. Department of Defense
DHS	U.S. Department of Homeland Security
DSCOVR	Deep Space Climate Observatory
ESPC	Earth System Prediction Capability
FAA	Federal Aviation Administration
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FMH	Federal Meteorological Handbook
GAO	U.S. Government Accountability Office
GOES	Geostationary Operational Environmental Satellite
GPO	U.S. Government Printing Office
GTS	Global Telecommunication System
ICAMS	Interagency Council for Advancing Meteorological Services
ICAO	International Civil Aviation Organization
ICAWS	Interagency Committee for Advancing Weather Services

ICMSSR	[OFCM] Interdepartmental Committee for Meteorological Services and Supporting Research
IHC	Interdepartmental Hurricane Conference
IMCO	Interagency Meteorological Coordination Office
ITAR	International Trade in Arms Regulations
IWXXM	ICAO Meteorological Information Exchange Model.
JAG	Joint Action Group
JAG/ICAWS	[OFCM] Joint Action Group for ICAWS Implementation
MPAR	Multifunction phased-array radar
MROS	[NWS] Manual Radiosonde Observing System
NASA	National Aeronautics and Space Administration
NESDIS	[NOAA] National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NPDIA	National Plan for Disaster Impact Assessments: Weather and Water Data
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Program / National Polar-orbiting Partnership
NSEM	Named Storm Event Model
NSF	National Science Foundation
NSSL	[NWS] National Severe Storm Laboratory
NSTC	National Science and Technology Council
NSWP	National Space Weather Program
NUOPC	National Unified Operational Prediction Capability
NWP	Numerical weather prediction
NWRT	National Weather Radar Testbed
NWS	National Weather Service

OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OMB	Office of Management and Budget
OSCAR	Observing Systems Capability Analysis and Review [database]
OSTP	Office of Science and Technology Policy
PDA	Product Distribution and Access
PROSWIFT	Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow [Act]
R&D	Research and development
RFI	Radio frequency interference
RRS	[NWS] Replacement Radiosonde System
SBEM	Space-based environmental monitoring
SENSR	Spectrum Efficient National Surveillance Radar
SHOUT	[NOAA] Sensing Hazards with Operational Unmanned Technology [program]
SWORM	Space Weather Operations, Research, and Mitigation
TAC	Traditional alphanumeric code
TCORF	Tropical Cyclone Operations and Research Forum
TCRF	Tropical Cyclone Research Forum
UAS	Unmanned automated system
WG/CCM	[OFCM] Working Group for Centralized Communications Management
WG/CSAB	[OFCM] Working Group for Cooperative Support and Backup
WG/DIAP	[OFCM] Working Group for Disaster Impact Assessments and Plans: Weather and Water Data
WG/ICCWD	[OFCM] Working Group on Interagency Coordination of Commercial Weather Data
WG/OD	[OFCM] Working Group for Observational Data
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization

WSI	WIGOS station identifier
WSR-88D	Weather Service Radar 1988 Doppler

Appendix 2
Periods of OFCM Service, Federal Coordinators of Meteorology and Deputy Federal Coordinators

Federal Coordinators		Deputy Federal Coordinators
Robert M. White, 1964–1972	1964	Donald J. Moore, 1964–1967
	1970	C. Edward Roache, 1967–1973
Richard E. Hallgren, 1972–1973		
C. Edward Roache, 1973		Vacant, 1974–1978
Clayton E. Jensen, 1973–1975		
Edward S. Epstein, 1975–1978		
Richard E. Hallgren, 1978–1979		Robert E. Beck, 1978–1980
Thomas B. Owen, 1979–1981	1980	William S. Barney, 1980
William S. Barney, 1981–1986		Alonzo Smith, 1981–1987
Robert L. Carnahan, 1986–1992	1990	Dr. James A. Alamazan, 1987–1993
Julian M. Wright, 1993–1998		James B. Harrison, 1993–2008
Samuel P. Williamson, 1998–2014	2000	
	2010	Michael R. Babcock, 2008–2011
		Col William Carle (USAF), 2012
		Col Gary Kubat (USAF), 2012–2014
David McCarren (USN), 2014–2015		Col Paul Roelle (USAF), 2014–2015
Col Paul Roelle (USAF), 2015		Michael Bonadonna, 2015–2018
William J. Schulz, 2015–2018		
Michael Bonadonna, 2018–2020		Vacant, 2018–2021
Neil Jacobs 2020	2020	
Richard Spinrad 2021-current		