WEATHER PROGRAM OFFICE
National Oceanic and Atmospheric Research

Annual Accomplishments

FY2020

A Weather-Ready Nation informed by world-class weather research

WPO Staff

(left to right)

First Row: Alison Agather[P]*, Henrique Alves[P], Tamara Battle*, Chantel Bivins*
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Third Row: Leah Dubots, Gina Eosco[P], Alice Grossman[P], Felicia Guarriello*
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Legend: Affiliates are denoted with an (*) and doctorates are denoted with a ([P])

(left to right)

First Row: Valbona Kunkel[P*], Sandra (Sandy) LaCorte*, Donald Long, Jr., Matthew Mahalik*
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Legend: Affiliates are denoted with an (*) and doctorates are denoted with a ([P])

Special thanks to our former employees and detailees for their contributions to the WPO Annual Accomplishments FY20 Report:

Kandis Boyd[P], Maureen Brooks [P*], Bonnie Brown[P*], John Cortinas[P], Shahaira Davy, Richard Fulton, Hernan Garcia[P], Daniel Melendez[P], Crystal Murphy*, Winnie Mutuli*, John Opatz*, Sarah Perfater*, Andrea Ray[P], Russell Schneider[P], Kathryn Shontz, and Segayle Thompson[P]

Annual Accomplishments

FY2020 >>

Letter from the Director

Dorothy Koch, PhD
NOAA Weather Program Office
June 2021

During a year marked by a global pandemic, NOAA's Office of Weather and Air Quality (OWAQ) adapted to a new virtual working environment, underwent internal changes, and officially became the NOAA Weather Program Office (WPO). Our office remained steadfast, diligently supporting scientists and research organizations in their engineering, physical, and social science efforts, keeping one main goal in mind:

Advancing and transitioning world-class weather research into operations and societal applications.

In pursuit of our vision and mission, WPO released its Fiscal Year 2021 (FY21) Notice of Funding Opportunity (NOFO) soliciting proposals in three research focus areas: weather, earth-system modeling, and social science. Strengthening our program portfolio, these three research areas foster collaboration, reflect multiple science objectives and address research questions that help us understand and predict our weather and climate.

WPO's weather enterprise partners are instrumental in conducting world-class research and transitioning its outcomes into operational products and applications. Alongside our stakeholder communities, we strive to understand how the public receives information, developing new tools to facilitate well-informed and effective weather-related decisions.

New scientific discoveries associated with the multi-year projects we fund assist us in granting equal access to all that WPO offers, pushing us towards our goal of diversity, equity, and inclusion (DEI) within and outside our office. WPO's staff and DEI working group have created avenues in all scientific disciplines of our NOFO, ensuring members of underrepresented communities have equal access to all the opportunities we offer.

As we continue to fulfill our goals, we celebrate the following achievements:

193

Total number of projects active in FY20: (increase from 184 in FY19), includng 303 total awards (increase from 276)

$50M

Budget remained steady: FY19 $50M; FY20 $50M

45%

% of Collaborative Projects (>1 institution) funded (increase from 39% in FY19)

As you will read in the following pages, our office funds research on weather out to seasonal timescales, utilizing social science to learn how to communicate uncertainties, building relationships with the broader scientific community. WPO's highly qualified staff ensures that our funded research contributes to saving lives, reducing property damage, and enhancing the national economy.

Our team is our strength, and throughout this year of coronavirus quarantine and social challenges, we will continue to foster networking and outreach capabilities in a virtual world.

Executive Summary

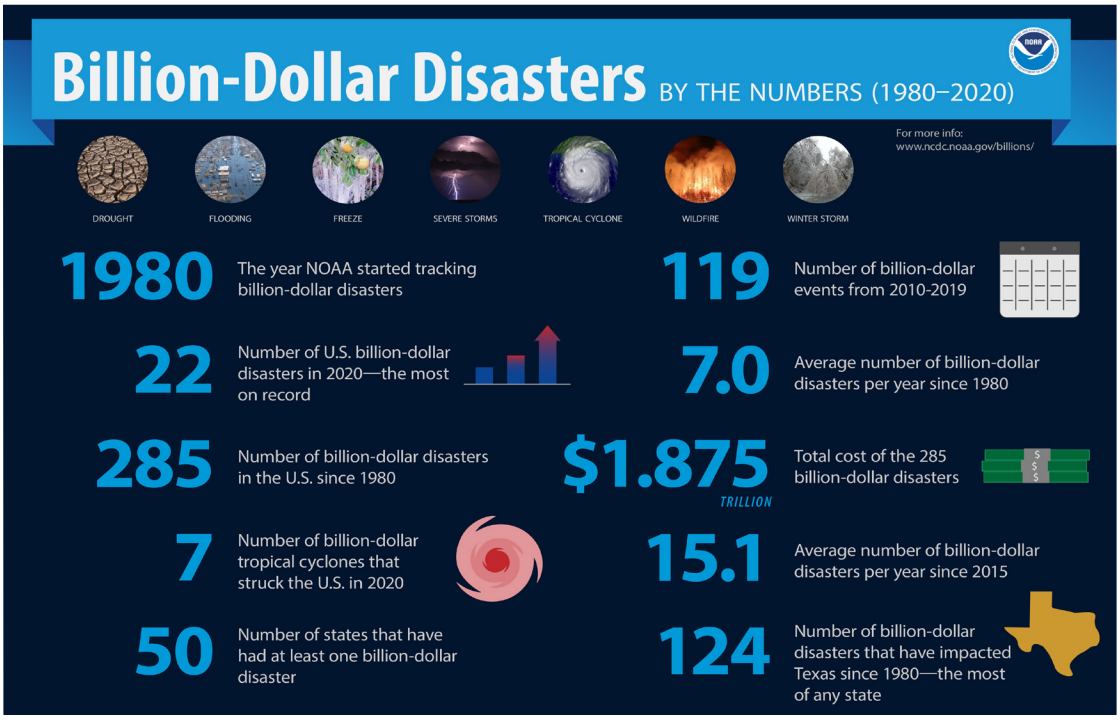


Figure 1. Billion-Dollar Disasters By the Numbers (1980-2020).[1]

A total of 22 weather/climate disaster[2] events impacted the United States in 2020, with losses exceeding $1 billion each. Drought, severe storms, tropical cyclones, and wildfires resulted in 262 deaths and significant economic impacts. For decades, the National Oceanic and Atmospheric Administration (NOAA) has been preparing society to effectively respond to weather and climate-related hazards, reducing the loss of life, property, and disruption from high-impact events like the hurricane and wildfire seasons of 2020.

The Office of Weather and Air Quality (OWAQ) was created to facilitate and fund weather research. As a part of NOAA Research's alignment in April 2020, OWAQ was renamed the NOAA Weather Program Office (WPO) to better reflect our mission and vision. Over the last ten years, WPO has remained focused on funding projects that have improved NOAA's forecast and its ability to provide timely and accurate forecasts, warnings and decision-making abilities for the greater community.

Vision & Mission

NOAA

Science, Service and Stewardship.

To understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources.

NOAA RESEARCH

Oceanic and Atmospheric Research (OAR)

Deliver NOAA's future.

Conduct research to understand and predict the Earth system; develop technology to improve NOAA science, service, and stewardship; and transition the results so they are useful to society.

WPO

A Weather-Ready Nation informed by world-class weather research.

Finding, funding, and fostering collaborative weather and air quality research to discover, develop, and transition products, tools, and services for timely and accurate weather and air quality forecasts.

WPO's vision, mission and goals are aligned with NOAA, its strategies for each Line Office[3], and the Department of Commerce. All are equally critical to WPO's ability to support world-class research to advance timely and accurate weather information.

WPO's goals also guide its efforts to build and sustain partnerships by funding weather-related projects that aim to strengthen decision-making and forecasting abilities.

GOAL 1

Improve effective communication of weather information to strengthen decision-making and forecasting ability.

Objective 1.1: Enhance the integration of Social, Behavioral, and Economic Sciences (SBES) into weather research and development to strengthen the utility of weather information for decision making.

Objective 1.2: SBES research findings into Weather Enterprise applications and, through engagement, identify gaps in support of future SBES research priorities.

GOAL 2

Advance models and forecast tools to produce the best weather forecasts and warnings to build a Weather-Ready Nation.

Objective 2.1: Advance the development and implementation of NOAA's Unified Forecast System (UFS).

Objective 2.2: Advance Subseasonal-to-Seasonal (S2S) forecasts.

Objective 2.3: Improve severe weather prediction capability.

GOAL 3

Effectively and efficiently manage the advancement and transition of weather research into societal applications.

Objective 3.1: Advance the development and transition of weather Research to Operations (R2O).

Objective 3.2: Ensure operations and management processes are well-documented, maintained, and refined.

Objective 3.3: Respond in a timely and effective manner to NOAA's congressional mandates.

GOAL 4

Develop and support a diverse and inclusive work environment that promotes equal access to the opportunities WPO offers.

Objective 4.1: Recruit and maintain a diverse and highly qualified workforce.

Objective 4.2: Promote and enhance the inclusion of WPO's diverse workforce.

Objective 4.3: Integrate and promote Diversity and Inclusion (D&I) as a core consideration throughout WPO's funding mechanisms.

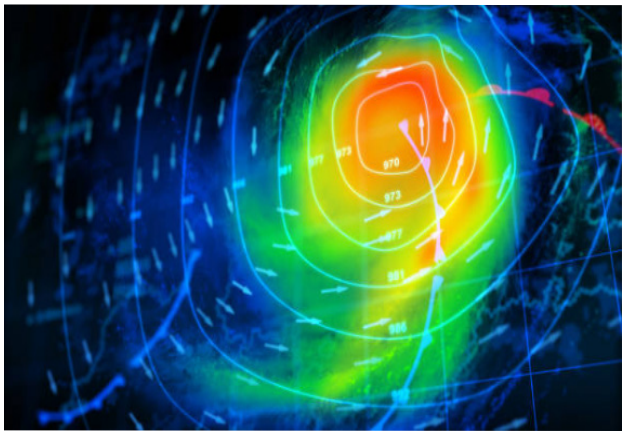


Figure 2. 3-D Image of a weather map.
Credit: Adobe Stock Images

Figure 3. ASOS at the Childress Municipal Airport in Childress, Texas. One of the 6 tools our meteorologist use to forecast weather.
Credit: NOAA

Our Approach

Our Mandate.

WPO's mission is largely driven by the Weather Research and Forecasting Innovation Act (Public Law 115-25), also referred to as the "Weather Act," which was codified by the 115th U.S. Congress in 2017. The Weather Act seeks to "improve the National Oceanic and Atmospheric Administration's weather research through a focused program of investment on affordable and attainable advances in observational, computing, and modeling capabilities to support substantial improvement in weather forecasting and prediction of high impact weather events." Among the priorities are research on hurricanes, tornadoes, subseasonal and seasonal forecasts, risk communication, and transition to operations.

Our Stakeholders.

To guide WPO's annual funding priorities, we work with stakeholders in the NOAA National Weather Service (NWS) and other NOAA line offices to develop funding calls in correlation with their strategic needs. The outcomes are better data, model improvements, post-processing tools, and communications knowledge that improve outreach. Although details of the process differ from program to program, they share the common goal of developing an annual Notice of Funding Opportunity (NOFO) that invites proposals from the academic community. Proposals compete for funding in calls that are categorized according to NOAA's Readiness Levels (RLs), and may specify developmental research at a low RL, or transitionable research at a high RL.

Our Partnerships.

WPO fosters a collaborative environment to support the transition of research into operational weather forecasting applications and help NOAA accomplish the mandates of the Weather Act. By coordinating research and development (R&D) projects with potential adopters and NOAA's Testbeds[4], WPO facilitates transition planning documents that are developed jointly between principal investigators and operational points of contact, allowing for alignment of goals at an early stage. In addition, a team of transition experts within WPO coordinates the process across its programs, working with NOAA management to regularly evaluate and improve the Agency's transition approach and maintaining project information in the NOAA Research and Development Database (NRDD).

Our Projects.

Over the past year, WPO increased the number of active R&D projects from 184 in Fiscal Year (FY) 2019 to 193 projects in FY2020, which include over 300 individual financial awards, totaling over $105 million. Research funding priorities are formulated in close coordination with partners from across the weather enterprise - a community that includes NOAA, other federal agencies, academia, research institutions, and the private sector. In addition, WPO manages 38 projects supported by $75 million disaster-related supplemental funding; funds several collaborative projects through Service Level Agreements (SLAs) with NWS; provides funding for NOAA's Testbed infrastructure; and manages the Unified Forecast System (UFS) R2O project.

Our Transitions.

Projects funded by WPO have a primary goal of advancing science and ultimately improving forecasts, by increasing knowledge and/or transition to operations. WPO coordinates with partners across NOAA and the weather enterprise to promote and facilitate R2O. Specifically, WPO and NWS collaborate to facilitate operational transitions through SLAs, plan research transitions, and improve the transition process itself. Our office invests in highly-qualified transition management staff who coordinate many of these activities.

In FY20, WPO's efforts contributed to the transition of four projects into NWS operations. An additional 21 projects delivered results to NWS, and await final operational use. The number of transition plans delivered to NWS for approval increased from 54 in FY19 to 71 (60% of all active transition projects) in FY20.

Our Commitment.

WPO's strategy is guided by the office's vision, mission, and goals and supported by the weather enterprise that includes NOAA; other federal agencies and entities; state, tribal, and local governments; academia; other not-for-profits; and the private sector. WPO promotes an energetic workforce that champions diversity, equity and inclusion (DEI) at NOAA by empowering our staff to comfortably and safely discuss inclusion and equity. In celebrating diversity, our office culture fosters a learning process that strengthens communication and trust. WPO has inspired other NOAA research laboratories and programs to start DEI conversations, which supports OAR's commitment to DEI.

WPO's annual NOFO provides a unique opportunity to encourage diverse research and increase inclusivity in funded projects. Inspired by the pioneering example from NOAA's Climate Program Office (CPO), WPO started including DEI language in its funding calls in FY19. Starting in FY20, all proposals submitted were required to feature a DEI statement. Encouraging outcomes point to more diverse collaborations and greater utilization of DEI in training programs, resulting in invaluable societal benefits. Additional steps have been taken to include DEI as scoring metrics in proposals submitted to WPO's FY21 NOFO.

WPO At-A-Glance

WPO's budget continued the increase that began in FY16, adding $50M in FY20 for a total increase of 123% since FY16. This has enabled a strategic investment portfolio in forecast models and tools, observations, risk communication, and technology transfers to operations, and included a new research initiative for the establishment of the Earth Prediction Innovation Center (EPIC).

WPO also funds various collaboration projects through the SLA between OAR and NWS. These projects involve support to testbeds, UFS development and implementation, and NWS S2S-related innovation and improvement needs.

The FY20 portfolio is summarized by extramural/intramural, readiness level, recipient type, geographic location, and metrics in Figures 4 through 9.

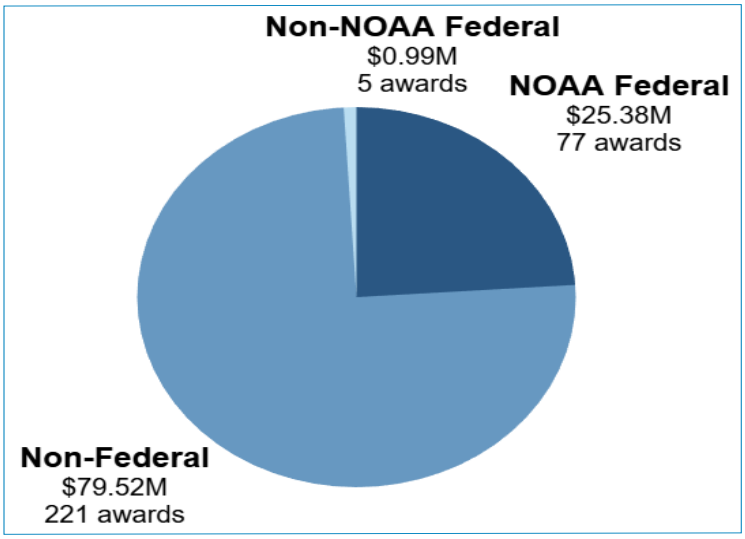


Figure 4. Distribution of total financial awards for active projects in FY20 by federal status.
Credit: Weather Program Office Metrics (2020)

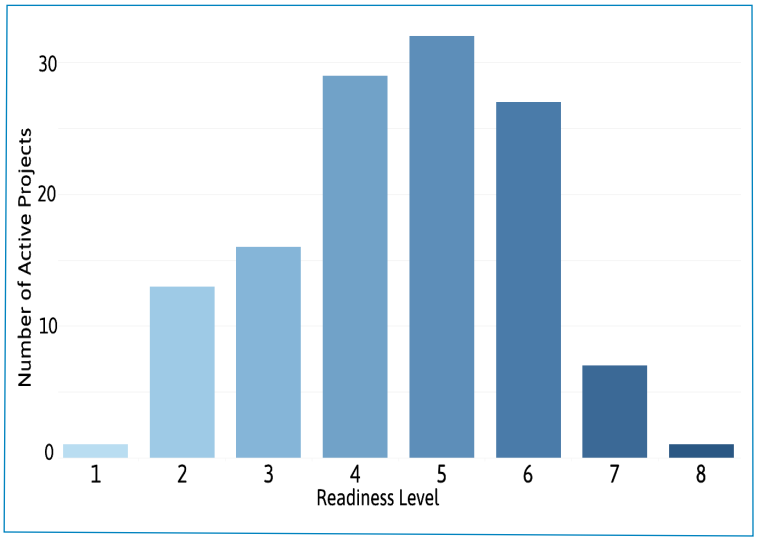


Figure 5. Distribution of active projects in FY20 by Readiness Level. Research projects range from basic research (RL1) to finalized system, process, product, service, or tool (RL8). After completing the WPO research path, RL8 products may transition to operations or application (RL9) at the discretion of adopters.
Credit: Weather Program Office Metrics (2020)

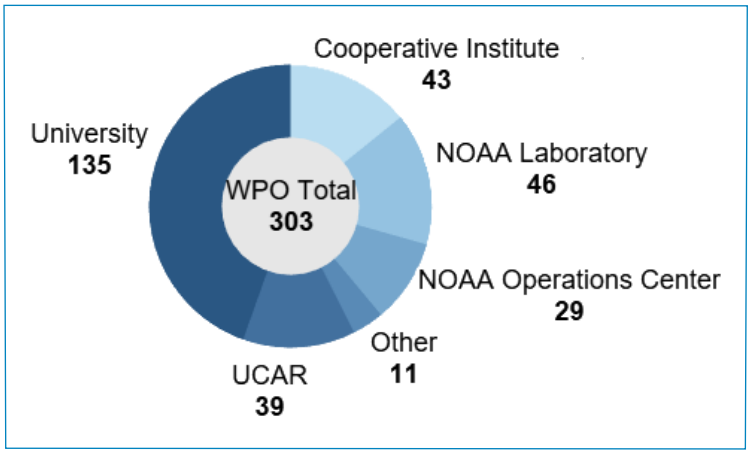


Figure 6. Distribution of WPO financial awards for active projects in FY20 by awardee institution type. "Other" awardees include private, non-profit, military, and non-NOAA federal institutions.
Credit: Weather Program Office Metrics (2020)

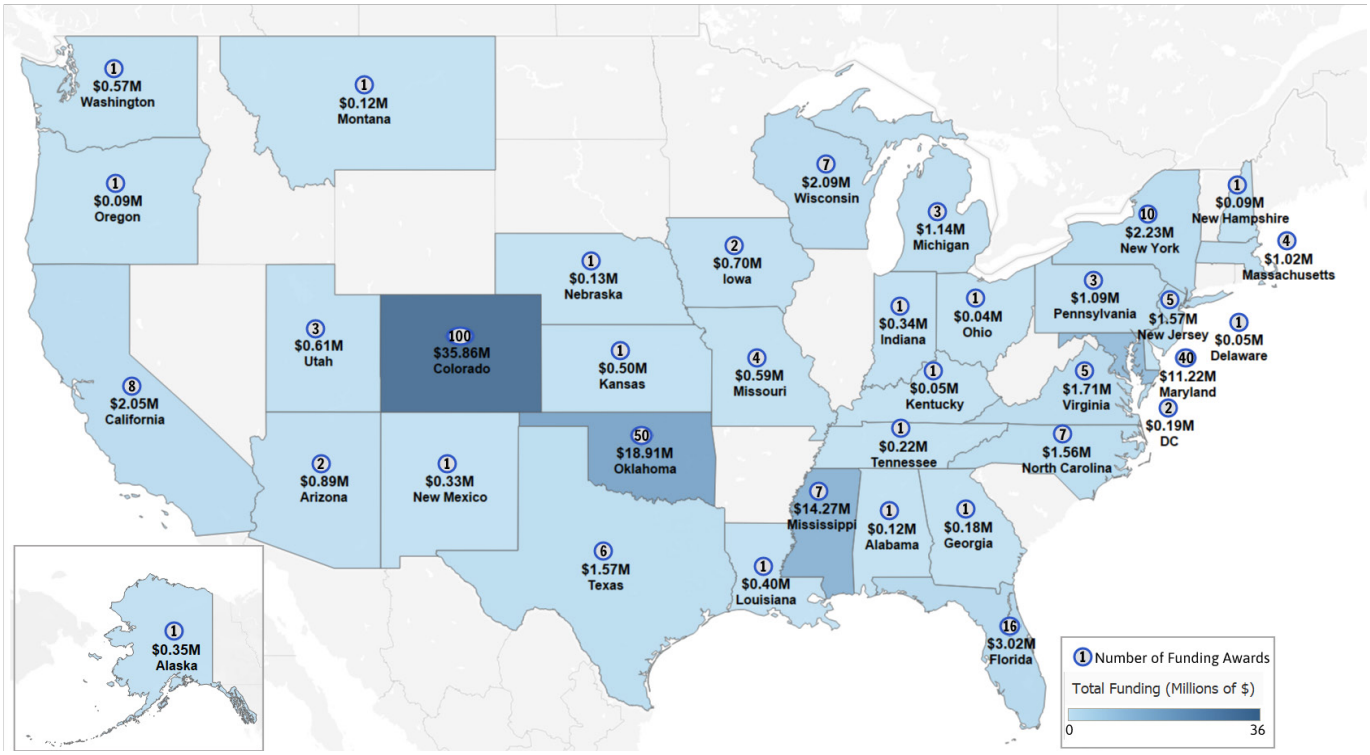


Figure 7. Locations and Amounts in FY20 by State.
Active Projects; Total Estimated Allocations, Rounded, including 85 Collaborative Projects Involving Institutions from Multiple U.S. States.
Credit: Weather Program Office Metrics (2020)

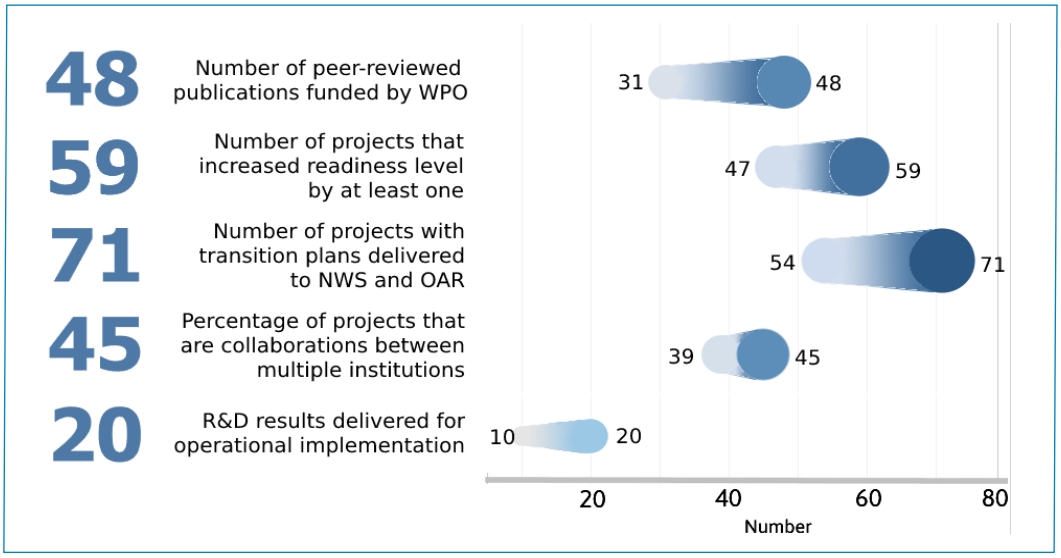


Figure 8. Weather Program Office by the Numbers for FY19, with a visualization of FY20 performance metrics compared to FY19.
Credit: Weather Program Office Annual Operating Plan FY20 (2020)

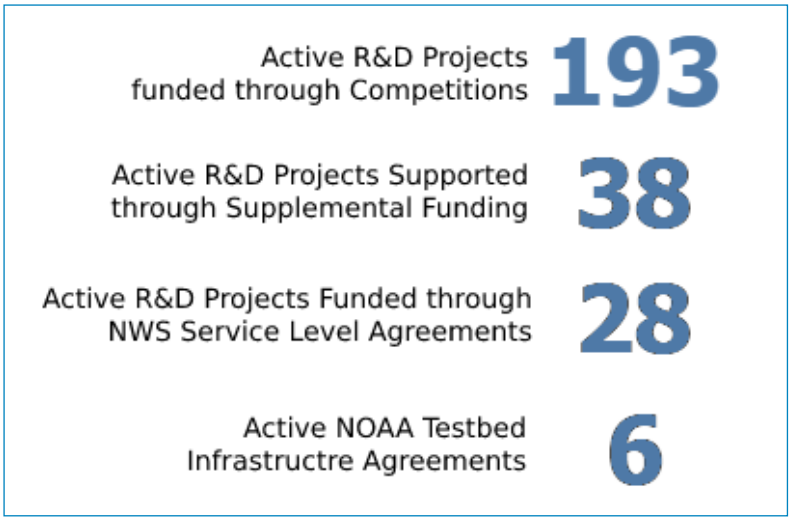


Figure 9. Number of projects and agreements active in FY20 by funding mechanism.
Credit: Weather Program Office Project Directory (2020)

Did you know?

The Weather Act is the most significant piece of legislation that Congress has passed for NOAA in over 25 years.

The NOAA Authorization Act of 1992 was the first which, among other things, mandated the creation of the U.S. Weather Research Program, which is managed by WPO.

We really like weather around here!

Overview of WPO Programs

WPO Programs work closely with our partners to fund, foster, and transition weather research through the continuous funding of active projects and call for new proposals in our annual funding opportunity. WPO's NOFO provides funding through awards that aim to improve knowledge about tropical cyclones, severe storms, extreme precipitation, air pollution, and social science – integrating weather, water, and climate forecasting and mitigation.

Our office hosts the following 10 programs:

- Air Quality Research and Forecasting (AQRF)
- Disaster-Related Appropriations Supplementals (DRAS)
- Earth Prediction Innovation Center (EPIC)
- Forecasting a Continuum of Environmental Threats (FACETs)
- Joint Technology Transfer Initiative (JTTI)
- National Earth System Prediction Capability (National ESPC)
- NOAA Testbeds - Hazardous Weather (HWT), Hydrometeorology (HMT) and Joint Hurricane (JHT)
- Social Science Program (SSP)
- Subseasonal to Seasonal (S2S)
- Weather Observations Research (Obs)

Further details about each WPO program are provided in the next few pages.

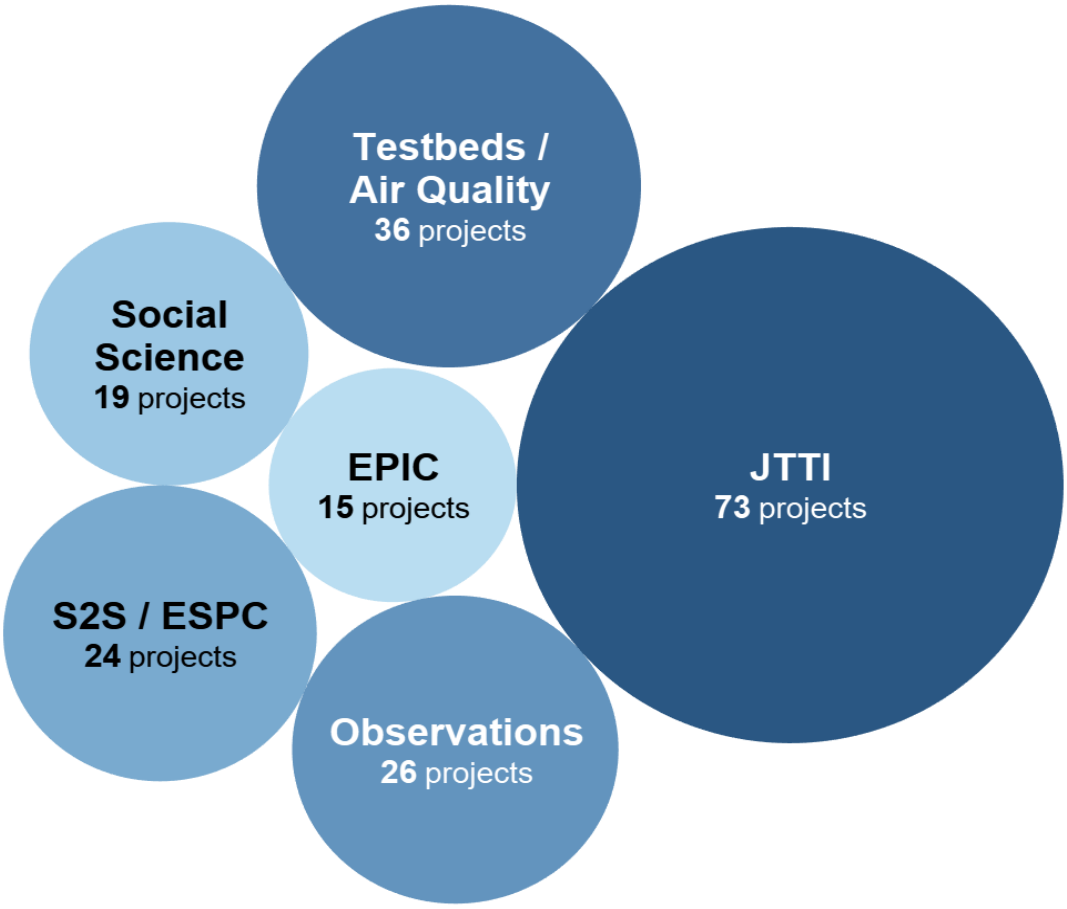
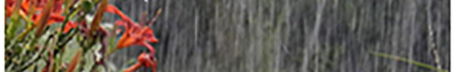
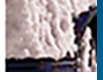


Figure 10. Distribution of the number of projects funded by WPO awards active during FY20 by the managing program. An additional 38 projects supported by disaster supplemental funding and 28 SLA projects with NWS are not included.
Credit: FY20 Weather Program Office Metrics (2020)



AQRF

Active Projects in FY20: 8
Number of Awards Active in FY20: 14
New Projects Funded in FY20: 0
(Next funding call anticipated in FY22)

The Air Quality Program aims to improve air quality forecast operations by focusing on strategic coordination and investments in air quality research and development. Six projects initiated in 2016 were completed in FY20. Four additional projects that began in 2019 are still ongoing through 2021.

DRAS

Active Projects in FY20: 38
Number of Awards Active in FY20: 50
New Projects Funded in FY20: 0

The Supplementals Program was mandated by the Bipartisan Budget Act of 2018 and includes research for weather, flood, and hurricane forecasting, wildfire prediction and data assimilation. In FY18, $50 million was allocated to Improving Forecasting and Assimilation (IFAA) and $25 million to the FY19 Improving Forecasts of Hurricanes, Floods, and Wildfires (IFHFW) portfolios. WPO jointly manages these Supplementals with other offices in NOAA's NWS, National Ocean Service (NOS), National Environmental, Satellite, and Data Information Service (NESDIS), and Office of Marine and Aviation Operations (OMAO). Many of these projects will leverage the UFS framework for research to operations transitions.

EPIC

Active Projects in FY20: 15
Number of Awards Active in FY20: 21
New Projects Funded in FY20: 7

EPIC will enable the most accurate and reliable operational numerical forecast model in the world by partnering with the non-scientific community and the weather enterprise to accelerate scientific research. In FY19 and FY20, the EPIC Program funded approximately 20 innovative projects and supported EPIC's core vision by community engagement activities, such as workshops, and through cross-agency and community partnerships to facilitate the use of cloud and high-performance computing resources.

FACETs

Active Projects in FY20: 5
Number of Awards Active in FY20: 9
New Projects Funded in FY20: 0

The FACETs Program focuses on modernizing the creation, communication, and effective dissemination of a continuous flow of risk-based, calibrated probabilistic hazard information to empower effective response. As a cross-cutting program, FACETs bridges meteorology, technology, and social sciences (among many others) to advance its framework. As a result, the FACETs Program works across OAR labs and programs and with NWS to nurture research collaborations and assist in the collaborative R2O transition process. In FY20, five projects (consisting of nine financial awards) funded and managed by the JTTI Program were part of the larger, cross-cutting FACETs initiative.

JTTI

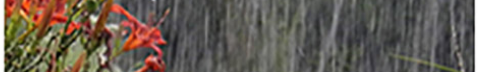
Active Projects in FY20: 73
Number of Awards Active in FY20: 120
New Projects Funded in FY20: 15

The JTTI Program was created by the U.S. Congress in 2016 to accelerate the transition of matured research from the weather enterprise to the NWS. The primary mission of the JTTI Program is to ensure continuous, cost-effective development and transition of the latest scientific and technological advancements into the NWS operations. Over the life of the program, JTTI has funded 107 projects, 14 of which have already transitioned to NWS operations. In addition, JTTI has provided funding for several projects managed by other WPO Programs (including EPIC, FACETs, and Observations), in addition to UFS and extended-range UFS SLA projects.

Did you know?

NOAA wants to hear from YOU?

The Earth Prediction Innovation Center (EPIC) Program was designed to support innovative community modeling projects to advance regional and global weather models. Opening access to its UFS code, EPIC and NOAA are looking for good ideas!

National ESPC

Active Projects in FY20: 1
Number of Awards Active in FY20: 2
New Projects Funded in FY20: 1

NOAA and other federal agencies collaborated within the National ESPC to establish a global prediction system in years past. Following the Weather Act renewal directive in 2019, the White House Office of Science and Technology Policy (OSTP) created the Interagency Council on Advancing Meteorological Services (ICAMS), which subsumed both the National ESPC and the Office of the Federal Coordinator for Meteorology in 2020. While maintaining National ESPC working groups, the National ESPC assisted in the transition of our oversight and organization. The group also funded part of an ongoing joint NOAA-Navy Modular Ocean Model version 6 (MOM6)/ HYbrid Coordinate Ocean Model (HYCOM) ocean modeling initiative to enhance NOAA/Navy ocean modeling collaboration.

NOAA HWT, JHT, and HMT

Active Projects in FY20: 28
Number of Awards Active in FY20: 31
New Projects Funded in FY20: 0
(Next funding call anticipated in FY22)

The NOAA Testbeds Program funds projects to test and demonstrate cutting-edge forecast technology in the NOAA weather testbeds to accelerate the technology transition to NWS forecast operations and improve NOAA's services to the public. WPO manages and executes funding to support projects and infrastructure costs associated with the JHT, HWT, and the HMT. Thirty-two projects have been funded through the Testbeds Program in the 2017 and 2019 fiscal years.

SSP

Active Projects in FY20: 19
Number of Awards Active in FY20: 24
New Projects Funded in FY20: 5

The SSP is dedicated to finding, funding, and fostering collaborative social science weather research and its potential applications. Social science is the study of people—what they think, how they feel, and how they respond—in a particular context. With recent societal impacts from hurricanes, floods, snowstorms, and wildfires, there has never been a greater need to understand the intersection of people and meteorology. Social science research findings often have implications for the 24/7 weather warning environment, including enhancing NWS products, tools, and services. It also has applications and benefits that guide the people, processes, policies, and organizations surrounding the R2O process. As such, SSP activities focus on nurturing relationships across NOAA and with the academic community to translate social science knowledge across the weather enterprise.

S2S

Active Projects in FY20: 30
Number of Awards Active in FY20: 41
New Projects Funded in FY20: 11

The S2S Program supports research on the time scales of two weeks to two years as required by the Weather Act. The program emphasizes increasing the understanding of predictability, advancing community-driven NOAA modeling initiatives and operational systems, and supporting the use and utility of multi-model ensembles for public, private, and academic users. In FY20, the program supported 10 ongoing, competitively-funded external projects totaling $2.4 million. These projects comprise community-based approaches to improving Earth system models, including NOAA's UFS, and improving existing ensembles to improve prediction skill and assessments of uncertainty. Financial assistance and oversight was also provided to ongoing multi-model ensemble efforts on the S2S and climate time scales.

Weather Observations Research

Active Projects in FY20: 26
Number of Awards Active in FY20: 44
New Projects Funded in FY20: 0
(Next funding call anticipated in FY21)

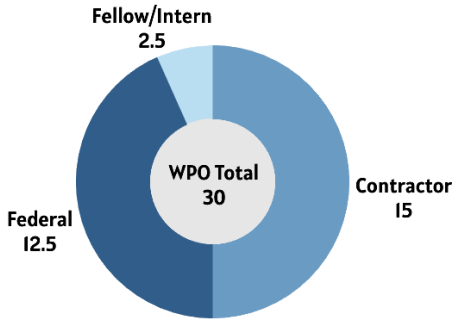
The Weather Observations Research Program supports research to improve weather observations technology critical for the detection and forecasting of hazardous weather phenomena. A recent National Academy Report titled *"Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks"* documented gaps, challenges, and priority needs to address inadequacies in the mesoscale weather observations needed to improve the forecasts, products, and services of the federal and weather enterprise. The program has embraced this challenge and strategically engaged with the weather observations research and operational communities in government, academia, and private industry to identify requirements, gaps and execute investment opportunities.

Our Team

As a reflection of the community-at-large, the projects we fund, and the partnerships that we have built, WPO has made a long-term commitment to maximize DEI. By placing people together with different characteristics, backgrounds, skills and experiences, WPO has been able to continue to support the mission and vision of the organization while fostering internal growth through an increase of staff from 25 to 30, and a conversion of five contractors into federal positions within or outside of WPO.

The following graphs provide an overview of WPO's staff dynamics:

a)



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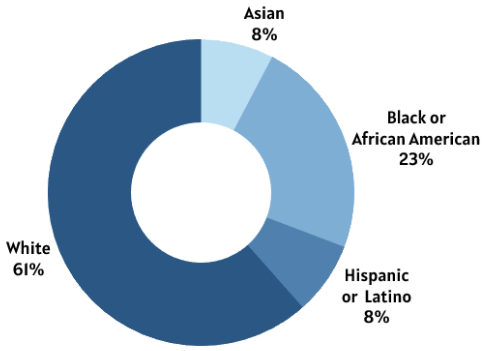

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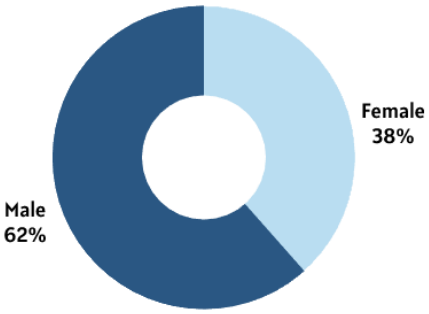

Figure 11. WPO diversity profiles for FY20, including breakdowns for (a) hiring authority, (b) race/ethnicity, and (c) gender.
(Note: Figures 11(a) and 11(b) represent Federal employees only).
Credit: Office of Oceanic and Atmospheric Research's Equal Employment Opportunity Program Office (2020)

WPO supports the development of new insights and the interdisciplinary technical expertise of our highly capable and diverse workforce through the implementation of WPO's vision and mission. Directly tied to a work environment that embodies the principles of diversity, equity and inclusion, WPO implements practices and procedures to ensure members of underrepresented communities have equal access to the opportunities we offer.

Read on about the outstanding work of our award-winning team!

Did you know?

In the United States, annual mortality from poor air quality substantially exceeds mortality from all other weather phenomena.

Four projects supported by WPO's Air Quality program are currently developing improvements to NOAA's air quality modeling systems to improve forecasts that are critical for protecting the American public.

We're making a difference!

Other WPO Achievements

On April 3, 2020, as a part of NOAA Research's re-alignment, the NOAA Office of Weather and Air Quality (OWAQ) was renamed the NOAA Weather Program Office (WPO) through a congressional mandate to better reflect our mission and contributions. All achievements performed prior to April 3, 2020 were performed as OWAQ, but will be referred to as WPO.

Notable Awards

Dr. Kandis Boyd received 2019 NOAA Administrator's Award

In November 2019, Dr. Kandis Boyd, WPO Deputy Director, received the NOAA Administrator's Award for her work on the #WomenofNOAA initiative that was created to celebrate the breadth of women in NOAA offices, labs, and the field that supports the agency's mission. The NOAA Administrator's Award recognizes employees who have demonstrated exceptional leadership, skill, and ingenuity in their significant, unique, and original contributions to NOAA, the Department of Commerce, and the Federal Government.

WPO honored for Diversity, Equity & Inclusion Efforts

In December 2019, under the guidance of Drs. John Cortinas and Kandis Boyd, WPO received the OAR Equal Employment Opportunity (EEO) Program/ Laboratory Award for community outreach efforts, collaboration with organizations who are aligned with WPO's goals to create a diverse and inclusive organizational culture, and expansion of the WPO staff to reflect the greater community at-large.

Dr. Kandis Boyd interviewed for 2020 Black Engineer of the Year Award (BEYA)

On February 6, 2020, Dr. Kandis Boyd, Acting WPO Director, was interviewed by WOLB Radio One for receiving the Career Achievement Award at the BEYA Science, Technology, Engineering, and Math (STEM) Conference, held from February 13-15, 2020. Each year, the BEYA STEM Conference brings professionals and students together for three days to share their experiences and career information, in support of its goal to create connections between students, educators and professionals while facilitating partnerships with individuals and their local STEM resources.

Workshops

WPO released the EPIC workshop and SubX project reports on November 22, 2019

WPO released the EPIC workshop report summarizing the presentations, discussions and community feedback gathered during the workshop held from August 6-8, 2019, at the University Memorial Center, University of Colorado Boulder. The workshop was spearheaded by WPO and convened by NOAA, and designed to engage the weather enterprise in the planning, development, and strategy for EPIC.

The SubX project report, which summarized the review held on August 19, 2019, focused on improving subseasonal predictions and largely targets the Week 3-4 outlooks from NOAA's Climate Prediction Center (CPC). SubX provides a research and experimental forecast dataset for the community to explore sources of subseasonal predictability and quantify the associated prediction skill in leading modeling systems.

WPO co-sponsored the 2020 Tropical Cyclone Operations and Research Forum

WPO, in conjunction with the Office of the Federal Coordinator of Meteorology (OFCM) and AOML, co-sponsored the 2020 Tropical Cyclone Operations and Research Forum held from February 26-27, 2020. The Forum was hosted by the NOAA Aircraft Operations Center in Lakeland, Florida, and included a presentation by Dr. Gina Eosco, Social Science and FACETs Program Manager, as well as engaging contributions from the WPO Team.

Scientific review of the UFS R2O proposal

In collaboration with NWS' Office of Science and Technology Integration (OSTI), WPO hosted a scientific review of the UFS R2O proposal held from March 12–13, 2020. Several international reviewers joined remotely for a scientific review of the proposal, which covered the 2-year development of the UFS at different spatial and time scales.

NOAA Snow Workshop

WPO collaborated with NWS to host the NOAA Snow Workshop held from March 18-19, 2020. This workshop pivoted from an in-person workshop to completely virtual within seven days due to the onset of COVID-19. The workshop was extremely successful and included a keynote address by Dr. Louis Uccellini, NWS Director, and identified requirements and gaps for snow observations. These outputs led to priorities in a WPO NOFO and documentation in a Bulletin of the American Meterological Society publication.

2nd Annual OAR Cloud Computing Workshop

The 2nd Annual OAR Cloud Computing Workshop was held virtually from July 20-23, 2020. Topics included existing cloud activities across OAR and planned pilot projects; an overview of OAR's use of NOAA's cloud utility contract; discussion of cloud requirements for High-Performance Computing (HPC) and non-HPC; panel discussion of how OAR can help facilitate the adoption of cloud; and next steps in the cloud development process.

Reports

WPO leads response to DOC comments on congressional radar report

In January 2020, WPO led the response to DOC's comments on NOAA's Report to Congress *"Weather Radar Follow-On Plan: Research and Risk Reduction to Inform Acquisition Decisions."* In conjunction with OAR's NSSL, NWS' Office of Observations and Radar Operations Center, WPO developed and coordinated content to address comments focused on the service life expectancy of the Next Generation Weather Radar (NEXRAD), cost of current radar operations and research and development, and the estimated $6.4 billion cost of recapitalization.

WPO & NOAA Library collaborate

On May 5, 2020, WPO, in conjunction with the NOAA Library, published the Weather Act collection page on the NOAA Institutional Repository website[5]. The collection provides access to documents submitted to Congress from NOAA's Line Offices in response to the Weather Act, describing NOAA's efforts and strategies to improve hurricane, tornado, tsunami, and seasonal forecasting, and commercial weather data. For more information, visit the Weather Act library guide[6].

Panels

Acting WPO Director moderated AMS Black History Month panel

On February 4, 2020, Dr. Kandis Boyd, WPO Acting Director, served on the 2020 AMS Black History Month panel co-hosted by the Board on Women and Minorities (BWM) and Board on Operation and Government Meteorologists (BOGM). This panel served as a space for people of all levels of experience to learn about the career paths of the panelists, including their challenges and successes.

WPO participates in the NOAA AI Strategy Implementation Workshop

Dr. DaNa Carlis presented a NOAA EPIC Strategy Overview during a panel discussion at the NOAA AI Strategy Implementation Workshop held from February 27-28, 2020. The purpose of the workshop was to develop the framework of the NOAA AI Strategy Implementation Plan, and evaluate the synergies between the NOAA Data, Cloud, and Unmanned Systems (UxS), the Omics Strategy, and EPIC to determine how the implementation plan supports the various NOAA Strategies.

The highlights above showcased how we effectively achieved our goals and prioritized engineering efforts and physical, social and behavioral sciences research. These new discoveries assisted the public in making real-time weather-related decisions. Our engagement and communication with researchers, funders, and the public remains instrumental in monitoring and understanding Earth's weather and air quality systems, to be more certain about what will happen this week, this month, and in the next two years.

WPO Research Focus Areas

WPO works closely with NOAA's research laboratories and the weather enterprise—a community that includes NOAA, other Federal agencies, academia, research institutions, and the private sector—to develop and transition weather research to improve knowledge about tropical cyclones, severe storms, extreme precipitation, air pollution, and social science. In addition, our office also seeks to integrate weather, water, and climate forecasting and mitigation.

In FY20, WPO fostered and transitioned research that was informed by social science, and focused on tropical cyclones, air quality & wildfires, severe weather, and climate/S2S forecasts, as well as the full use of artificial intelligence in prediction. These broad areas are illustrative but do not represent the breadth of research that WPO supports.

Each of these research focus areas cuts across multiple WPO Programs. Such an integrated approach is best explained by a description presented of selected projects illustrating how WPO supports "A Weather-Ready Nation informed by world-class weather research."

Tropical Cyclones

Tropical cyclones are heat-driven cyclonic storm systems that form over tropical or subtropical waters. Known variously as hurricanes (Atlantic and Eastern Pacific Oceans), typhoons (Northwestern Pacific), and tropical cyclones (South Pacific and Indian Ocean), their impacts can be devastating: winds and storm surge can cause deaths and devastating property losses, ranging from damaged roads and bridges to destroyed homes and businesses.

The 2020 North Atlantic hurricane season was the most active on record, with 30 named storms, including 13 hurricanes, six major hurricanes, and a record 11 tropical cyclones that made landfall in the contiguous United States. NOAA tropical cyclone research aims to improve the ability of forecasters to predict their occurrence and effectively communicate associated hazards to the public. NOAA's JHT continues to be an important partner in testing, evaluating, and accelerating development of tropical cyclone forecasting tools, technologies, and techniques.

In FY20, approximately 10% of active WPO-funded projects contributed to tropical cyclone research. Including the following highlights:

Figure 12. Hurricane Earth Satellite Tracking.
Credit: IstockPhoto

WPO's hurricane and tropical cyclone FY20 research priorities plan to:

1. Improve operational analysis of the surface wind field in tropical cyclones.
2. Identify new applications of ensemble modeling systems for track, intensity, and structure forecasting.
3. Improve tropical cyclone genesis and intensity guidance.
4. Advance coastal inundation modeling and/or applications, visualization, and/or dissemination technology.
5. Develop probabilistic wave height forecasts.
6. Integrate relevant social and behavioral science methodologies to improve forecasters' use of convection allowing/resolving data, techniques, and guidance, as well as end-users' ability to receive, assess, understand, and respond to forecasts and warnings.

Did you know?

The 2020 Spring Forecasting Experiment was entirely virtual.

The Hazardous Weather Testbed (HWT), which is supported by WPO, hosted its first-ever 100% virtual Spring Forecast Experiment in April-May 2020. Despite it being completely virtual, over 80 forecasters and researchers participated in the meeting.

Way to go!

Improving Predictive Modeling for Hurricanes

Physics and improved vertical resolution for improving hurricane prediction and tropical convection in the GFS

Dr. Lucas Harris, Mr. Linjiong Zhou, Mr. Kun Gao, and Mr. Morris Bender,
Princeton University/NOAA Geophysical Fluid Dynamics Laboratory (GFDL)

Improvements in hurricane intensity forecasts can save lives. Global Forecast System (GFS) predictions of hurricane intensity have become more accurate over the last several years, as model resolution increases and parameterizations are improved. GFDL has continually made improvements to SHiELD (System for High-resolution Prediction on Earth-to-Local Domains) by improving the FV3 Dynamical Core, GFDL microphysics, PBL (Planetary Boundary Layer) scheme, and surface interactions. In 2020, both 13-km global SHiELD and 3-km nested T-SHiELD performed comparably in intensity skill with operational models. Notably, T-SHiELD had a very low bias, maintaining intensity well over the lifetime of the forecast without over-intensification. 13-km SHiELD also showed intensity skill on par with specialized hurricane models -- a first for any global model.

As improvements in SHiELD and other UFS configurations continue, and GFSv17 becomes operational as part of the Unified Forecasting System (UFS), the National Hurricane Center (NHC) will benefit from these improvements in hurricane intensity forecasts.

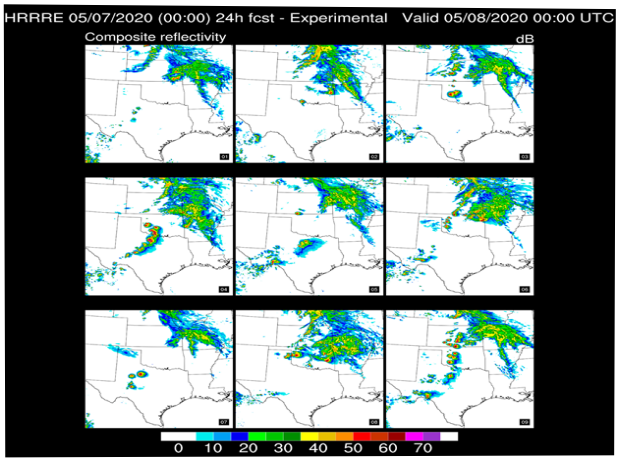

Figure 13. With a combination of IC perturbations, BC perturbations, SPP, and SPPT, we achieved our goal of producing large spread in convective-storm forecasts with a single-model, single-physics ensemble. Final Report 2020, Figure 10 on page 10.
Credit: Alexander, et al.

Increasing the Prediction Accuracy of Hurricanes

Enhancing the Prediction of Landfalling Hurricanes Through Improved Data Assimilation with the Gridpoint Statistical I (GSI)-based Ensemble-Variational Hybrid System and Joint Effort for Data assimilation Integration (JEDI)

Dr. Zhaoxia Pu
University of Utah

Gridpoint Statistical Interpolation-based ensemble-variational hybrid system and the Joint Center for Satellite Data Assimilation's (JCSDA) JEDI for predictions of time, location, inland evolution, intensity and structure changes of landfalling hurricanes. Advances are possible: (1) by enhancing the assimilation of satellite-measured ocean surface wind and surface Mesonet observations on land and of ground-based NEXRAD observations; and (2) from incorporating new observations from the hurricane inner-core region.

This research meets several JTTI priorities, primarily by strengthening predictions for intensity and track of landfalling hurricanes for current operational hurricane forecast models, such as the GFS-FV3.

Hurricane Boundary Layer Wind Observations

New, Three-Dimensional, Hurricane Boundary Layer Winds from the Imaging Wind and Rain Airborne Profiler (IWRAP) Radar

Dr. Zorana Jelenak
University Corporation for Atmospheric Research (UCAR)
Dr. Stephen Guimond
University of Maryland - Baltimore County (UMBC)
Dr. Paul Chang
NOAA NESDIS

This project will provide next-generation observations of the three-dimensional (3D) hurricane boundary layer (HBL) and ocean surface vector winds (OSVW) from the NOAA WP-3D aircraft, utilizing the IWRAP. IWRAP is a powerful instrument that can fully capture large, turbulent gusts of wind throughout the extent of the HBL, which is not possible from in-situ measurements such as dropsondes. The IWRAP observations will be provided in real-time to the NHC and will be of significant value to forecasters providing warnings for damaging winds and storm surge. In addition, the observations can be used to improve numerical weather prediction models through data assimilation and optimizing turbulence parameterizations.

Advancing New Radar Technologies

Airborne Phased Array Radar (APAR)

Dr. Vanda Grubišić
NCAR Earth Observing Laboratory (EOL)

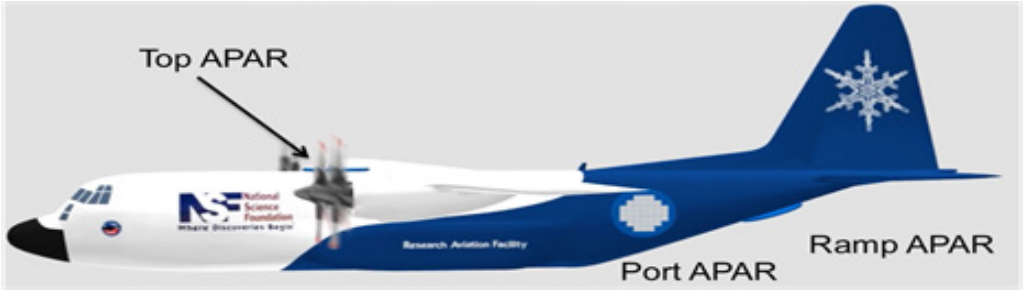

Figure 14. C-130 with Airbore Phased Array Radar (APAR) Panels.
Credit: UCAR/NCAR - Earth Observing Laboratory. (1994). NSF/NCARHercules C130 Aircraft. UCAR/NCAR - Earth Observing Laboratory.

Airborne weather radars are the most effective instruments available for observing storms over complex terrain, oceans, polar regions, and forested areas. Once developed, APAR will fill the critical need for a fast-scanning weather radar with deep storm penetrating capability and will be available to the research community for 20-25 years through the well-established request process for National Science Foundation's (NSF's) Lower Atmosphere Observing Facilities (LAOF).

An airborne weather radar such as APAR will also directly support NOAA's long-term mission and goal of developing America's capabilities as a "weather-ready" nation and directly addresses NOAA's strategic objective of providing improved understanding and timely alerting of severe and adverse weather events. It will also help advance the goal of an operational APAR on the aircraft used by the NHC for flights into hurricanes for greater storm analysis, such as the NSF/NCAR C-130 aircraft by 2028 and the next-generation NOAA hurricane hunter aircraft by 2030.

Assessing the Public's Consumption of Changing Tropical Cyclone Forecasts Over Time

Wait, that Forecast Changed? Assessing How Public's Consume and Process Changing Tropical Cyclone (TC) Forecasts Over Time

Dr. Rebecca Morss, Dr. Julie Demuth, Mr. Robert Presley, Ms. Andrea Schumacher, Mr. Josh Alland
NCAR
Ms. Gabrielle Wong-Parodi, Ms. Natalie Herbert
Stanford University
Ms. Leysia Palen, Mr. Ken Anderson, Ms. Melissa Bica
University of Colorado-Boulder

To learn more about how the public consumes and processes tropical cyclone information in the modern information environment, this project deployed a longitudinal survey before, during, and after Hurricanes Marco and Laura (2020) to investigate how at-risk people process, understand, and use the complex collection of evolving forecast and warning information available during a tropical cyclone threat. This includes examining whether and when members of the public anchor on forecast information and how they shift their risk perception as updated tropical cyclone forecast information emerges.

Did you know?

The Weather Observations Research Program is actually 3 programs in 1.

The WPO Weather Observations Research Program (WORP) not only supports projects for severe storm observations, but also infrasonic detection of severe weather, as well as soil moisture and snowpack measurements. This means the Obs Program effectively and affordably observes weather and climate from the ground up.

That's a lot to cover!

Air Quality and Wildfires

In many areas of the country, the public is exposed to unhealthy levels of air pollutants and sensitive ecosystems are damaged by air pollution. Among other hazards, wildfires, high surface ozone, and other pollutants contribute to poor air quality.

In 2020, a record-setting wildfire season affected the Western U.S. California experienced five of its six largest wildfires on record, resulting in widespread smoke and haze. In the East, heat waves, high humidity, and urban pollution combined to produce hazardous air quality conditions. NOAA works with the Environmental Protection Agency, state and local air quality agencies, academia, and the private sector to address these problems, providing an air quality forecast capability for the nation called the National Air Quality Forecasting Capability.

Figure 15. California Smog.
Credit: NOAA ESRL Atmospheric Turbulence & Diffusion Division

WPO's air quality and wildfires FY20 research priorities plan to:

1. Develop and evaluate high-resolution (1–4 km) air quality forecast capabilities that are consistent with NOAA weather forecast models at these resolutions.
2. Improve spatial and temporal estimates of anthropogenic and natural pollutant emissions.
3. Explore and quantify the potential value of ensemble model approaches and post processing to operational air quality forecasting.
4. Improve model representation in the FV3 model of physical/chemical processes for long-range transport.
5. Develop high-density observation capabilities that quantify how extreme temperatures, combined with dew point and wind speed, impact air quality and outdoor activities.

In FY20, approximately 10% of active WPO-funded projects contributed to air quality and wildfire research, including the following highlights:

Improving the Forecasts of Smoke from Wildfires

Top-Down Estimation of Wildfire Smoke Emission Based on HYSPLIT Model and NOAA NESDIS GOES Aerosol/Smoke Products to Improve Smoke Forecasts in the U.S.

Dr. Tianfeng Chai
University of Maryland (UMD)

Researchers intend to provide a better smoke forecast by developing a Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) inversion system to better estimate wildfire smoke sources.

Researchers plan to evaluate and improve the inverse system while working on real-time operation capability. Proposed actions include:

- Transitioning the inverse system code to the NOAA operational environment, if appropriate;
- Modifying the code interface to read near-real-time GOES Aerosol/Smoke Products; and
- Evaluating the smoke forecasts using the optimally estimated emissions.

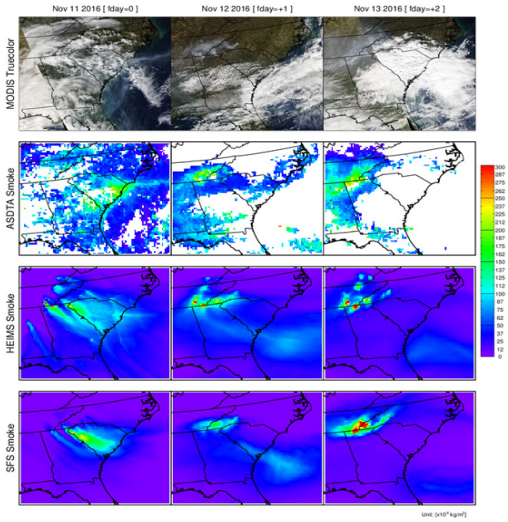

Figure 16. Observed and HYSPLIT predicted smoke plumes.

Rows 1-3:
1) MODIS True color images;
2) GOES smoke products;
3) Predictions after inverse modeling;
4) Operational NOAA smoke forecasts.

Columns 1-3:
Nov. 11/12/13, 2016.

Credit: Kim, H. C., Chai, T., Stein, A., and Kondragunta, S.: Inverse modeling of fire emissions constrained by smoke plume transport using HYSPLIT dispersion model and geostationary satellite observations, Atmos. Chem. Phys., 20, 10259-10277, doi:10.5194/acp-20-10259-2020, 2020

Assessing and Communicating Uncertainty in Modeled Transport, Dispersion, and Deposition of Hazardous Materials

Using HYSPLIT Ensemble Dispersion Modeling for Forecasting Applications

Drs. Barbara Stunder & Alice Crawford
NOAA Air Resources Laboratory (ARL)

Researchers intend to improve on deterministic approaches with products that assess and communicate uncertainty in the modeling of hazardous material transport, dispersion, and deposition.

The results may serve emergency response applications as diverse as simulating atmospheric plumes from chemical releases and volcanic ash.

Severe Weather

The term “severe weather” is used to describe local, intense, often-damaging storms such as thunderstorms, severe wind and hail storms, and tornadoes. Annually, the U.S. is struck by 100,000 thunderstorms,10,000 severe thunderstorms, and 1,000 tornadoes.

NOAA’s severe weather research aims to improve forecaster ability to predict and communicate warnings to the general public. NOAA’s Hazardous Weather Testbed continues to be an important partner in testing, evaluating, and accelerating development of severe weather tools, technologies, and forecasting and communication techniques.

WPO’s severe weather FY20 research priorities plan to:

1. Identify and validate concepts and techniques to improve NOAA’s convection-allowing/resolving ensemble forecast system performance.
2. Identify and validate innovative post-processing and verification techniques for NOAA’s deterministic models and ensembles across spatial and temporal scales to create skillful and reliable probabilistic thunderstorm and severe hazard threat guidance.
3. Improve numerical weather prediction modeling through data assimilation, post-processing, and verification capabilities.
4. Advance technologies that characterize boundary layer vertical profiles of water vapor, temperature, pressure, and winds.
5. Integrate relevant social and behavioral science methodologies to improve forecasters’ use of convection allowing/resolving data, techniques, and guidance, as well as end-users’ ability to receive, assess, understand, and respond to forecasts and warnings.

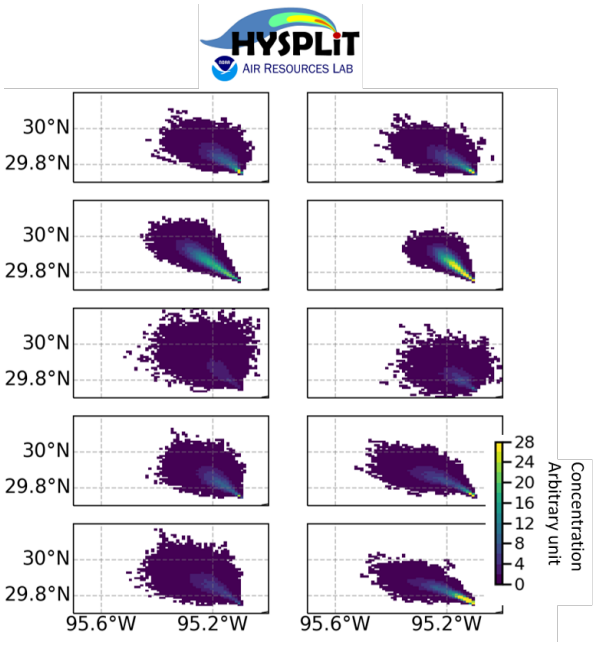

Figure 17. Ensemble plume forecast for a hypothetical release of a hazardous substance in Deer Park, TX. The ensemble forecast is produced using HYSPLIT driven by the ten members of the HREF (high resolution ensemble forecast). The ensemble members convey uncertainty in concentration due to uncertainties in meteorological conditions. The individual members shown here can be combined to provide information such as the probability that a critical concentration will be exceeded.
Credit: Stunder, et al.

In FY20, approximately 20% of active WPO-funded projects contributed to severe weather research, including the following highlights:

Advancing Convection-Allowing Models with Objective Mode Identification

Using Convective Mode Information for Hazard Prediction With Convection-Allowing Models

Mr. Ryan Sobash
NCAR

Researchers intend to employ and then assess a convective mode identification system in the post-processing workflow of the NOAA HWT Community Leveraged Unified Ensemble (CLUE). Existing algorithms will be used to build the system, which will be objectively and subjectively tested in the HWT. The model-agnostic system will be refined for use with various new and current guidance products, and for potential validation of convection-mode forecasts.

Resulting research products will be accessible to the public and to NOAA stakeholders (e.g., scientists, forecasters) in organizations such as NOAA’s Storm Prediction Center (SPC), NSSL, and the HWT.

Improving Research-to-Operations Transitions for FACETs

FACETs: Advancing Physical and Social Science Concepts Toward Operational Implementation of Probabilistic Hazard Information

Mr. Alan Gerard
NOAA NSSL

This project continues the R2O transition process for key aspects of the FACETs effort for convective hazards, and will elevate the RLs of physical and social science concepts that serve as foundations for FACETs. Collaboration with the NWS will also support and improve current services and programs related to convective hazards through targeted transitions to operations.

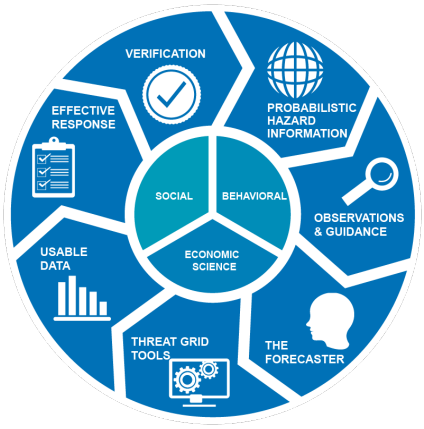

Figure 18. Depiction of the seven facets of the FACETs research-to-operations paradigm with social/behavioral/economic sciences integrated throughout the framework.
Credit: NOAA NSSL

FACETs is a proposed next-generation watch and warning framework that is designed to communicate clear and simple hazardous weather information to the public. FACETs supports NOAA's Weather-Ready Nation initiative to build community resilience in the face of increasing vulnerability to extreme weather events.

Understanding How the Public Responds to Forecasts and Warnings

Communicating Forecast Uncertainty and Probabilistic Information: Experimenting with Social Observation Data in the Hazardous Weather Testbed

Drs. Carol Silva and Joseph Ripberger
University of Oklahoma (OU)

Researchers seek to improve communication of forecast uncertainty and probabilistic information by building upon the Severe Weather and Society Survey, a new data collection capacity that provides generalizable, longitudinal, and experimental data on how members of the U.S. public receive, understand, and respond to uncertainty and probabilistic information in severe weather forecasts and warnings. Although still in development, current data are available[7]. To ensure a smooth transition from research to operations, researchers will engage with the National Weather Service's Warning Decision Training Division before, during, and after the Hazardous Weather Testbed experiment.

Improving Hazardous Weather Prediction

Convection-Allowing Model Ensembles Optimal Configuration for Short and Longer Time Scales and Multigrid Background Error Covariance Model

Dr. Curtis Alexander
NOAA Earth System Research Laboratory, GSL
Dr. Jacob Carley
NOAA Environmental Modeling Center (EMC)
Dr. Nusrat Yussouf
University of Oklahoma - Cooperative Institute for Mesoscale Meteorological Studies (OU CIMMS)/NSSL

Researchers explored the optimal ensemble design for probabilistic forecasts of hazardous weather threats that represents forecast errors in the 0-6 hour time frame, as well as the 0-36 hour time frame. Researchers also worked to improve the quality and structure of the analysis increment in the data assimilation system through the development of a multi-grid beta filter to model the background error covariance, the development also addresses computational bottlenecks present in the existing operational infrastructure.

Development of these capabilities supports the Unified Forecast System and forms a foundation for success in the National Centers for Environmental Prediction's future high-resolution modeling and forecast capabilities in the Rapid Refresh Forecast System, Warn-on-Forecast System, and 3D Real Time and UnRestricted Mesoscale Analysis system.

Did you know?

The FACETs framework was originally developed to revolutionize severe storm monitoring? It now aims to expand in the near future to include hurricanes, flooding and ice storms.

This will definitely keep us on our toes!

Artificial Intelligence

NOAA recognizes the potential of artificial intelligence (AI) and machine learning (ML) techniques to advance capabilities in analyzing the expansive amount of data collected by observing networks and produced by modeling systems. AI analytics and cloud computing platforms are being leveraged to identify, understand, and forecast extreme weather events of all types, including severe weather, flooding, tropical cyclones, subseasonal to seasonal, and others. R&D funded through WPO aims to support the advancement of AI applications to better extract information from data, thereby enabling better analyses and predictions.

WPO's AI/ML FY20 research priorities plan to:

1. In collaboration with the UFS community, further develop, test and enhance data assimilation techniques, develop and evaluate physics, improve model component coupling techniques and capabilities, and utilize AI/ML for improving forecasts.
2. Accelerate the use of AI in product generation in operations, particularly for better use of existing ensembles, and creation of auto-tuning and auto-calibration capabilities for machine learning techniques to reduce operations and maintenance costs.
3. Improve climate- and S2S-scale model post-processing via innovative statistical techniques and applications of existing statistical techniques, AI/ML methods.

AI is a new but rapidly growing component of WPO's research portfolio and is a part of less than 10% of active WPO projects in FY2020. Examples of WPO AI-focused projects follow.

Figure 19. Hologram with planet earth and binary code on background symmetrical data center with rows of supercomputers.
Credit: Vladmir TImofeev/IstockPhoto

Using Deep Learning to Analyze Fronts

Deep Learning for Operational Identification and Prediction of Synoptic-Scale Fronts

Dr. Amy McGovern
University of Oklahoma (OU)
Dr. John Allen
Central Michigan University

Researchers will develop an automated ML approach for frontal analysis that may be integrated into regular analysis procedures by human forecasters. ML will provide a first-guess map for warm, cold, occluded, and stationary fronts, as well as drylines, over the region covered by the Unified Surface Analysis. An effective, automated first-guess map will allow human forecasters to significantly reduce the time needed to produce a final analysis. This project will make use of deep learning, which has recently emerged as a high-performing ML algorithm in a variety of fields.

Calibrated Forecast Guidance for Severe Weather

Generating calibrated forecast guidance for severe weather beyond Day 1

Drs. Russ Schumacher and Aaron Hill
Colorado State University

Severe weather predictions pose significant challenges for forecasters, especially past the short range (less than 2 days) when fewer forecast tools are available. In this project, a severe weather ML model will be extended to post-process global model output and produce CONUS-wide forecasts of severe weather to aid SPC forecasters at days 2-8 (36-204 hours). The project will leverage the new Unified Forecast System FV3-based Global Ensemble Forecast System (GEFSv12), which became operational in September 2020, as input to the ML model and generate probabilistic severe weather forecasts. Researchers will objectively and subjectively evaluate the probabilistic forecasts at the Hazardous Weather Testbed Spring Forecast Experiment and with SPC forecasters.

Did you know?

JTTI is celebrating a significant anniversary?

The Joint Technology Transfer Initiative (JTTI) program was created in 2016, to accelerate the transition of matured research from America's Weather Enterprise to NWS.

Happy 5th Anniversary, JTTI!

Climate/S2S

Long-range weather and climate predictability on the scale of S2S and beyond remains a challenging area of research. Through the S2S competitive call and the Climate Testbed, WPO supports a wide range of research toward developing a baseline of S2S predictability, community-based approaches to improving Earth system models, and improving existing ensembles to improve prediction skill and assessments of uncertainty. Together, these begin to fulfill the S2S (defined as a forecast period of two weeks to two years) requirements of the Weather Act while emphasizing the models and components in NOAA's UFS, the North American Multi-Model Ensemble, and ongoing multi-model ensemble efforts on the S2S timescale (e.g. the continuation of the Subseasonal Experiment and support to the S2S datasets at the International Research Institute for Climate and Society's Data Library).

Figure 20. Derechos are known for having a swath of wind damage extend for more than 240 miles and include wind gusts of at least 58 mph, or greater, along most of its length.
Credit: Jim Reed/Corbis via Getty Images

WPO's climate/S2S FY20 research priorities plan to:

1. Improve climate-scale model post-processing via innovative statistical techniques and applications of existing statistical techniques, AI/ML methods.
2. Accelerate the S2S portion of the UFS through new methods or improvements to existing scale- and aerosol aware parameterizations.
3. Enhance data assimilation systems that support climate monitoring and prediction, specifically related to ocean, sea ice, and land data assimilation using the JEDI.

In FY20, approximately 15% of WPO-funded projects contributed to climate and S2S research, including the following highlights:

Evaluating Seasonal and Subseasonal Forecasts

Applications of Model Evaluation Tools (METplus) to Subseasonal Climate Outlooks, Multi-Model Ensembles, Process Studies, and Extremes

Ms. Tara Jensen
NCAR
Ms. Melissa Ou
NOAA NWS/CPC

Utilizing the METplus to enhance the capability of evaluating seasonal and subseasonal official outlooks and model guidance, this project aims to improve these forecasts by better understanding their skill. Results will determine how well models replicate climatological characteristics and the ability of models and post-processed tools to forecast hazards and extremes using various types of thresholds.

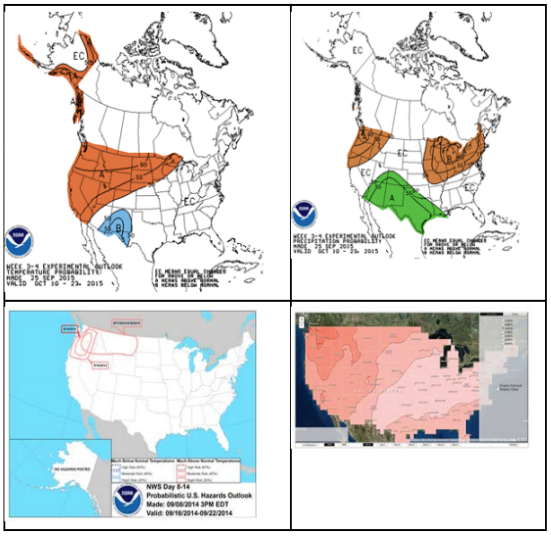

Figure 21. Examples of temperature and precipitation guidance. (a) Top Left: Example of the Climate Prediction Center (CPC)'s experimental weeks 3-4 temperature forecast. (b) Top Right: Example of CPC's weeks 3-4 precipitation forecast. (c) Bottom Left: Example of CPC's week-2 official, probabilistic hazards forecast for temperature, based on guidance from the GEFS Reforecast Tool (Bottom Right).
Credit: Tara Jensen (2020)

Improving Subseasonal to Seasonal Prediction in the UFS

Accelerating Progress in Subseasonal to Seasonal Prediction Capabilities by Improving Subgrid-Scale Parameterizations in the UFS

Dr. Benjamin W. Green
Cooperative Institute for Research in Environmental Sciences (CIRES) / University of Colorado-Boulder/ NOAA GSL
Dr. Vijay Tallapragada
NOAA NWS

In this project, researchers test the impact of incorporating three new parameterizations of atmospheric subgrid-scale physical processes into the existing physics suite used for NOAA's UFS. The intent is to advance S2S prediction capabilities, including forecasts of precipitation and temperature, over the U.S. and globally. The gains in S2S forecast skill will result from testing and evaluating the new parameterization schemes and comparing their performance against current operational parameterizations of scale-aware convection, planetary boundary layer, and cloud microphysics maintained by NOAA's EMC.

Improving 2-4 Week Precipitation

Identifying physical processes responsible for tropical UFS errors and their relation to UFS week 2-4 precipitation predictability in the western US

Drs. Juliana Dias and Elizabeth Thompson
NOAA PSL
Dr. Shan Sun
NOAA GSL

Part of NOAA's Precipitation Grand Challenge initiative, this project aims to quantify improvements in western U.S. precipitation forecasts at 2-4 week lead times. Improvements are expected from reducing tropical sources of uncertainty related to subseasonal limits of predictability, lack of observational constraints, systematic model errors, and model parameterizations. This will help advance work toward the improvement of predictions of the amounts and locations of rain and snow, as well as other precipitation-related forecasts.

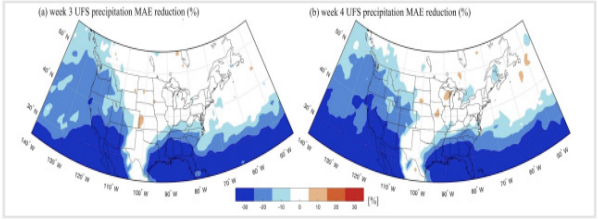

Figure 23. Illustration of U.S. areas where UFS week 3-4 precipitation error is reduced (blue) when nudging is applied to the tropical atmosphere. Shading shows percent differences in mean absolute error (MAE) of precipitation if the entire tropical atmosphere is nudged to reanalysis. Reforecast period is November-March (1999-2018).
Credit: Juliana Dias, 2020

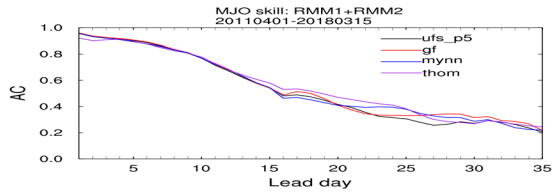

Figure 22. Bivariate skill score for the RMM index, indicating skill of forecasting the Madden-Julian Oscillation (MJO). Each curve represents the aggregate skill of a particular experiment: the control is in black, GF convection in red, MYNN boundary layer in blue, and Thompson microphysics in purple. The green dashed line denotes a score of 0.6; scores above this are considered to be skillful. Thus, the Thompson experiment is skillful beyond 14 days, whereas the other 3 experiments are skillful beyond 13 days.
Credit: Benjamin W. Green (2021)

Did you know?

The U.S. Congress has provided supplemental funds to NOAA to support recovery from high-impact weather events?

In 2013, the 114th U.S. Congress provided funding to NOAA to improve and streamline disaster assistance, and study the impacts of Super Storm Sandy.

Water

Precipitation, ocean modeling, flooding, snowpack and soil moisture all contribute to WPO's precipitation and hydrologic research focus area. Flooding is the result of an overflow or inundation from a river or other body of water that causes or threatens damage. Annually, the U.S. is struck by over 5,000 floods or flash floods. Coastal storms, heavy rain, and melting snow are all potential causes. When flooding is on coastal lands, it is termed "coastal inundation." Although it could be caused by wave action, it is usually the result of riverine flooding, spring tides, severe storms, or underwater seismic activity resulting in a tsunami. WPO precipitation and hydrology research is focused on improving observations and forecasts of heavy precipitation, snowpack, soil moisture, and flooding threats, in addition to improving ocean and rivershed modeling capabilities. NOAA's HMT continues to be an important partner in testing, evaluating, and accelerating development of hydrologic forecasting tools, technologies, and techniques.

WPO's water FY20 research priorities plan to:

1. Identify and validate new or improved methods, models, or decision-support tools to improve flash-flood monitoring and forecasting.
2. Identify and validate new or improved methods, data assimilation, models, or decision-support tools to improve utilization of precipitation forecasts and production of streamflow forecasts.
3. Identify and validate new or improved methods, models, or decision-support tools to improve probabilistic winter precipitation forecasts for snowfall amounts and/or ice accumulation.
4. Improve water prediction capabilities to include efforts to enhance hydrologic prediction through improved data assimilation and model extension for hydrological data sets.
5. Focus on advancements leading to improved surface-based or airborne-based observing capabilities of snow depth (snow water equivalent) and soil moisture.
6. Improve observations, data assimilation, and physics parameterization of snow depth and soil moisture.

In FY20, approximately 20% of active WPO-funded projects contributed to water hazard research, including the following highlights:

Detecting Snow with Remote Sensing

Experimental Framework for Testing the National Water Model: Operationalizing the Use of Snow Remote Sensing in Alaska

Dr. Katrina Bennett
Los Alamos National Laboratory
Dr. Vladimir Alexeev
University of Alaska - Fairbanks
Ms. Aubrey Dugger
Research Applications Lab

This project will develop a near-real-time data stream of simple, first-order assimilation of remotely sensed snow cover extent and snow water equivalent data in Alaska. The components of this work will be operationalized for use in NOAA's Community Hydrologic Prediction System (CHPS) framework. Researchers also will develop a first-ever experimental NWM for Alaska river basins to test, validate, and benchmark NWM model skill to better capture the processes critical to hydrologic prediction in Alaska.

Evaluating Heavy Rainfall and Flash Flooding Forecasts

Probabilistic Warn-on-Forecast System for Heavy Rainfall and Flash Flooding

Mr. Steven Martinaitis
University of Oklahoma - Cooperative Institute for Mesoscale Meteorological Studies (OU CIMMS)/NSSL
Dr. Jonathan Gourley
NOAA NSSL

This project uses the HMT Multi-Radar Multi-Sensor (MRMS) Hydro Experiment with the goal of evaluating new probabilistic products and methodologies for forecasting heavy rainfall and flash flooding within the Flooded Locations and Simulated Hydrographs (FLASH) system while incorporating short-term forecasts from NOAA NSSL's Warn-on-Forecast system model.

Researchers presented the latest research developments and techniques to forecasters for optimizing probabilistic products coupled with short-term ensemble modeling for eventual use in the NWS' flash flood warning operations. Findings from the experiment have shown the potential for increasing warning lead times and reducing false alarm area.

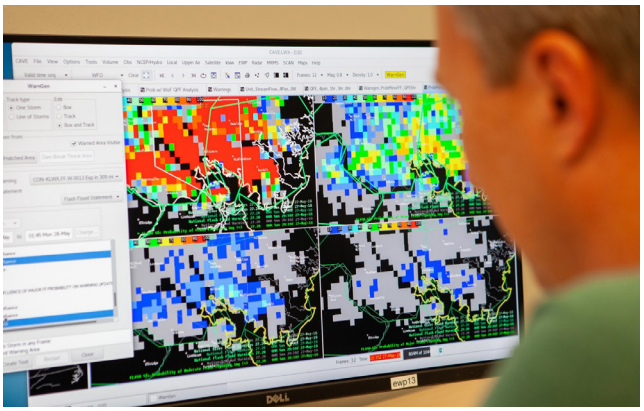

Figure 24. A participating forecaster issues a flash flood warning based on probabilistic FLASH data coupled with Warn-on-Forecast precipitation forecasts during a simulation of the 27 May 2018 Ellicott City, MD event. *Credit:* James Murnan/NOAA

Leveraging High Resolution Terrain Data to Address National Water Model Limitations

Estimating Inundation Extent and Depth from National Water Model Outputs and High Resolution Topographic Data

Dr. Paola Passalacqua
University of Texas - Austin

This work addresses shortcomings in the NWM for predicting flood inundation extent and depth by using the workflow GeoFlood, which draws on NWM output and high resolution terrain (HRT) data for increased accuracy of the river network and terrain elevation. NWM output uses 10m resolution terrain data, which are overlaid on 3m or finer HRT data, thus misplacing NHDPlus medium range centerlines with regards to visible channel location in the HRT.

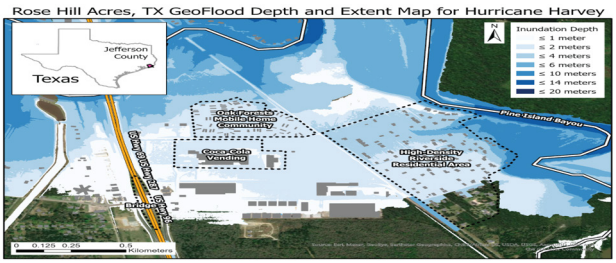

Figure 25. Example of methods and products in Jefferson County. Rose Hill Acres straddles Highway 96/69/287 approximately 10 mi north of Beaumont, TX. Local residents evacuated as Harvey caused flood waters to rise at a peak rate of 0.15 m/hour. The flood inundation map was generated by GeoFlood from lidar data at 1m resolution and refers to conditions observed on 8/29/2017. Average processing time to obtain GeoFlood inundation maps is 5 seconds per HUC12.
Credit: Dr. Paola Passalacqua

GeoFlood corrects the issue by applying geodesic minimization principles and topographic attributes computed using HRT data, and then employing the Height Above Nearest Drainage (HAND) method. GeoFlood will eventually enable seamless transition from 10m resolution to 1m products with expansion of HRT data coverage (Passalacqua 2019).

Social Science

NOAA must communicate clear and simple weather information that serves the public, which is why social science must inform every aspect of weather forecasting, including providing well-informed and effective warnings. WPO and its partners coordinate social science research needs, determine approaches to translating social science research to applications, and learn from the operational community to understand the next research challenges.

Figure 26. Tennessee Severe Weather Alert.

Social Science priorities were informed by WPO's goals, especially to improve effective communication of weather information to strengthen decision-making and forecasting ability.

WPO's social science FY20 research priorities plan to:

1. Develop and test methodologies that systematically collect data on end users, including forecaster needs in the operational decision environment, measuring the effectiveness of Impact-Based Decision Support Services (IDSS), and measuring how the public receives, interprets, perceives, and responds to weather information.
2. Improve visual and verbal communication of forecast risk and uncertainty, including probabilistic forecast information.

In FY20, approximately 15% of active projects funded by WPO contributed to social science research priorities, including the following highlights:

Helping the Public Understand Uncertainty

Making Sense of Uncertainty: Improving the Use of Hydrologic Probabilistic Information in Decision-Making

Ms. Rachel Carr
Nurture Nature Center

This research builds on a series of studies conducted by the research team since 2012, each of which is centered on how professional and residential users understand flood and hydrologic forecasts, including those representing uncertainty and probabilistic information.

Accomplishments include the development of a series of user-tested prototype products, developed in cooperation with operational offices and advanced toward operational use, as well as a final report with findings, general recommendations for probabilistic communication, and an explanatory video about the project's findings.

Understanding the Value of Improving Hurricane Forecasts

A Web-Based Survey to Estimate the Economic Value of Improved Hurricane Forecasts

Dr. David Letson, Dr. Renato Molina, Brian McNoldy
NOAA AOML
Dr. Pallab Mozumder,
Florida International University

The Hurricane Forecast Improvement Program prioritizes hurricane research that improves hurricane track, intensity, and storm surge forecasts. By focusing on areas recently hit by Hurricanes Florence and Michael, this project merged atmospheric modeling to estimate the value of improvements in storm track, wind speed, and precipitation forecast precision. Preliminary results based on this sample suggest that the public values these dimensions of forecast improvement a minimum of $327 million per year across regions that are vulnerable to hurricanes.

Using Social and Behavioral Data to Improve Forecast Communication

Communicating Forecast Uncertainty and Probabilistic Information: Expanding and Embedding Social and Behavioral Data in National Weather Service Operations

Dr. Joseph Ripberger
University of Oklahoma (OU)

This project will improve forecast communication and decision support during extreme weather and high impact weather events by building upon the Severe Weather and Society Survey and the Severe Weather and Society Dashboard. Results will provide generalizable, longitudinal, and experimental data on how members of the Continental U.S. public receive, understand, and respond to uncertainty and probabilistic information in severe weather forecasts and warnings. This information can then be used in future operations to more effectively communicate forecasts to the general public.

The Way Forward

WPO aims to further our collaborative efforts within NOAA and with our stakeholders, partners, the public and the weather enterprise by supporting WPO's 10 Programs. In concurrence with congressional mandates and our goals, WPO Programs will continue to manage the creation and implementation of research tools and applications through the transition of research into operations or knowledge.

Over the next couple of months, WPO will reassess its mission, goals, structure, and connections in preparation for the 5-year update to our Strategic Plan. This plan guides WPO in prioritizing weather research that saves lives, reduces property damages, and enhances the national economy. In addition, WPO will continue to promote a diverse, equitable, and inclusive research and work environment that supports and fosters collaborations through our annual NOFO.

As we move ahead, ongoing innovation, the funding of weather-related projects, and building upon or expanding our relationships will remain top priorities for WPO as we prepare for our future.

To help navigate the best path ahead, WPO will support the continued emergent NOAA research focus areas:

- Improving methods for incorporating data into forecast models and for model coupling to improve weather forecasting operations from hourly to seasonal time scales.
- Testing/developing the coupled (sub-hourly to subseasonal timescale) UFS; accelerate the S2S application of the UFS.
- Improving forecasts of extreme weather and high-impact weather events.
- Understanding and reducing societal vulnerability to tornadoes and other high-impact events.
- Researching operational NWS and partners' forecast and warning decision-making process and public response.
- Improving risk communication, risk perception, and information use in protective decision-making.
- Improving model post-processing via innovative statistical techniques and the use of AI/ML methods.

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Goal 1

WPO will continue improving communication of weather research information to community and strategic partners by:

- Connecting theoretical knowledge about behavioral responses to predictions, warnings, and forecasts in specific domains.
- Improving the transition of social and behavioral research into operational processes.
- Improving dissemination of ideas and best practices to stakeholders.

Did you know?

WPO's Social Science Program (SSP) is breaking new ground at NOAA?

The SSP is leading NOAA's efforts in determining the valuation of its research outputs, and how to successfully transfer knowledge to NWS operations.

Nicely done, SSP!

Goal 2

WPO will advance and transition models and forecast tools by focusing on applied research.

- UFS and EPIC. Continue testing for the coupled (hourly to subseasonal time scales) UFS, leveraging high-performance computing resources and machine learning techniques. WPO will continue developing EPIC as a true community-sourced modeling framework and leveraging cloud computing resources to advance models and forecast tools.
- S2S. Develop and mature the S2S portions of the UFS, with specifics in the Strategic Implementation Plan emphasis areas.
- Severe weather. Improve forecasts of extreme weather and high-impact weather events, including hurricanes, tornadoes, and fire-weather. Develop improved methods for incorporating data into forecast modeling and for model coupling to improve weather forecasting operations. Continue to support VORTEX-SE and tornado research funding.
- Air quality. Continue funding improved air quality research and forecasting, especially to improve the NOAA operational forecast for fine particulate matter ($PM_{2.5}$) and ozone predictions. Improve assessing and modeling emissions from sources such as wildfire smoke and dust as well as chemical mechanisms.
- FACETs. Coordinate with the FACETs Program to inform program initiatives and objectives.
- Tropical Social Science. Review emergent Tropical Social Science research findings and the NWS Tropical Program to work toward a social science transition plan.
- Congressional mandates. Continue activities in support of the Weather Act and the NIDIS Reauthorization. In coordination with the Interagency Council for Advancing Meteorological Services, continue the U.S. Weather Research Program Implementation Plan and supporting interagency working groups.

Did you know?

S2S had an identity crisis?

Before 2017, there was much confusion about the timescale that S2S represented--different users and different researchers defined it according to their needs. The Weather Act changed that, by officially defining S2S as the timescale from 2 weeks to 2 years.

Well, that sums it up!

WEATHER PROGRAM OFFICE
National Oceanic and Atmospheric Research

Goal 3

WPO recognizes that a diverse workforce enhances our efforts to advance and support the mission of science, service, and stewardship within NOAA and with the external community. WPO will:

- Continue to assemble a diverse workforce seeking the best talent from all sources. Workforce diversity helps ensure that interdisciplinary demands for weather research and development expertise are continuously met through a work environment that encourages open communication, provides fair and equitable opportunities, and empowers employees with the resources and support they need.
- Include a wider range of participants in our research activities by revising our NOFO to place greater selection emphasis on outreach, education, diversity, equity and inclusion.
- Understand and respond to the needs of WPO's partners and stakeholders, including under-served groups.
- Improve the overall diversity of the weather enterprise by strengthening engagement with underrepresented groups, particularly with NOAA's Cooperative Science Centers, Historically-Black Colleges and Universities, Hispanic-Serving Institutions, Minoroity-Serving Insitutions, and Tribal Colleges and Universities.

Conclusion

Fulfilling our mission frequently encounters challenges and a global pandemic topped that list in 2020. WPO's internally cohesive team, composed of Federal employees and contractors, completed our annual funding cycle in spite of disruptions; NOAA provided administrative flexibilities enabling our world-class scientists to succeed despite these arduous challenges. WPO looks forward to continuing to partner with the weather enterprise to provide the research underpinning a Weather-Ready Nation for 2021 and beyond.

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Social Media

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@NOAA_WPO

Appendices

References

[1]Figure 1. Billion-Dollar Weather and Climate Disasters: Overview (2021)

[2]Record Number of billion-dollar disasters struck U.S. in 2020 (NOAA)

[3]NOAA Corporate Finance and Administrative Services Offices - NOAA Line Offices

[4]NOAA Testbeds and Proving Grounds Portal

[5]NOAA Institutional Repository website

[6]Weather Act library guide

[7]Understanding How the Public Responds to Forecasts and Warnings Weather Dash
(Drs. Carol Silva & Joseph Ripberger, OU)

Project Directory

In support of our vision and mission, the projects listed in the Project Directory are selected and funded by WPO through our funding opportunities. These projects promote a diverse and inclusive research environment, foster collaboration that transitions world-class research into operations and help to ensure timely and accurate weather and air quality forecasts that benefit society by saving lives, reducing property damage, and enhancing the national economy.

Photo Credits

From left to right

Top Row: *Blue sky and white clouds over the sea.*
Credit: Carlos Machado

GOESR and full Earth.
Credit: NOAA

The Sun Meets the Rain on St. Thomas, U.S. Virgin Islands.
Credit: Elena Kobrinski

Third Row: *High water.*
Credit: iStock

Ocean.
Credit: Stock Photo

Lake Superior.
Credit:Todd Marsee, MI Sea Grant

Second Row: *A heat wave and smog shown by the shoreline in Chicago.*
Credit: iStock

A supercell thunderstorm in Kansas
Credit: Mike Coniglio/NOAA NSSL

Snow Flood.
Credit: NOAA

Fourth Row: *Land Atmosphere.*
Credit: NOAA ESRL

San Luis Reservoir In Gustine California
Credit: NOAA NCEI

Green field Landscape stock photo
Credit: iStock

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Acronyms

Abbreviations/Acronyms	Definitions	Context for Use
AGU	American Geophysical Union	Partner-Not-for-profit
AI	Artificial Intelligence	
AMS	American Meterological Society	Partner-Not-for-profit
AOML	Atlantic Oceanograhic and Meteorological Laboratory	NOAA Lab
AOP	Annual Operating Plan	Structure
APAR	Airborner Phased Array Radar	Equipment
AQRF	Air Quality Research and Forecasting	Sub-program
ARL	Air Resources Laboratory	NOAA Lab
AWC	Aviation Weather Center	NOAA Center
AWPS	Advanced Weather Interactive Processing System	Model or System
BEYA	Black Engineer of the Year Award	Award
C-SUITE	Comprizon Suite (C Request and C Award)	Structure
CICS (M)	Cooperative Institute for Climate and Satellites	
CICS (P)	Cooperative Institute for Climate Science	
CIFAR	Cooperative Institute for Alaska Research	
CIGLR	Cooperative Institute for Great Lakes Research	
CIMAS	Cooperative Institute for Marine and Atmospheric Studies	
CIMEC	Cooperative Institute for Marine Ecosystems and Climate	
CIMMS	Cooperative Institute for Meteorological Satellite Studies	
CIMRS	Cooperative Institute for Marine Resources Studies	
CIMSS	Cooperative Institute for Meteorological Satellite Studies	
CINAR	Cooperative Institute for the North Atlantic Region	
CIGERT	Cooperative Institute for Ocean Exploration, Research and Technology	
CIPIR (aka JMAR)	Cooperative Institute for the Pacifica Island Region (Joint Institute for Marine and Atmospheric Science)	
CIRA	Cooperative Institute for Research in the Atmosphere	
CIRES	Cooperative Institute for Research in Enviornmental Studies	
CPC	Climate Prediction Center	
CPO	Climate Program Office (within OAR)	
DOC	Department of Commerce	
DRAS	Disaster-Related Appropriations Supplemental	
EEO	Equal Employment Opportunity	
EOL	Earth Observing Laboratory	
EPIC	Earth Prediction Innovation Center	

EMC	Environmental Modeling Center	
ESPC	Earth System Prediction Capability	
ESRL-RASM	Earth System Research Laboratory - Regional Arctic System Model	Model
ESRL/GSL	Global Systems Laboratory	NOAA Lab
ESRL/PSL	Physical Sciences Laboratory	NOAA Lab
FACETs	Forecasting a Continuum of Environmental Threats	
FY	Fiscal Year	
GFDL	Geophysical Fluid Dynamics Laboratory	
GFS	Global Forecast Systesm	Numerical weather prediction model
GLERL	Great Lakes Environmental Research Laboratory	NOAA Lab
GOL	Grants Online	
GSI	Gridpoint Statistical Interpretation	
HMT	Hydrometeorology Testbed	
HPC	High Peformance Computing	
HRT	High resolution terrian	
HYCOM	HYbrid Coordinate Ocean Model	
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory	Model
ICAMS	Interagency Council for Advancing Meteorological Services	
IWRAP	Imaging Wind and Rain Airborne Profiler	
JEDI	Joint Effort for Data Assimilation	
JHT	Joint Hurricane Testbed	
JISAO	Joint Institute for the Study of the Atmopshere and Ocean	
JTTI	Joint Technology Transfer Initiative	
LO	Line Office	
ML	Machine Learning	
MOM	Modular Ocean Model	
MRMS	Multi-Radar Multi-Sensor	
NAS	National Academy of Sciences	
NCAR	National Center for Atmospheric Research	
NESDIS	National Environmental Satellite, Data, and Information Service	NOAA Line Office
NEXRAD	Next Generation Radar	
NGGPS	Next Generation Global Prediction System	
NHC	National Hurricane Center	
NMFS	National Marine Fisheries Service	
NOAA	National Oceanic and Atmospheric Administration	
NOFO	Notice of Funding Opportunity	
NOS	National Ocean Service	NOAA Line Office
NRDD	NOAA Research and Development Database	Portal for research projects

NSF	National Science Foundation	
NSSL	National Severe Storms Laboratory	NOAA Lab
NWS	National Weather Service	NOAA Line Office
O2R	Operations to Research	
OAP	Ocean Acidification Program (within OAR)	
OAR	Oceanic and Atmospheric Research	NOAA Line Office
OMAO	Office of Marine and Aviation Observations	NOAA Line Office
OSTI	Office of Science and Technology Integration	
OSTP	The White House Office of Science and Technology Policy	
OU	University of Oklahoma	
OWAQ	Office of Weather and Air Quality	
PI	Principal Investigator	
PBL	Planetary Boundary Layer	
R&D	Research and Development	
R2O	Research to Operations	
RFI	Request for Information	
RL	Readiness Level	
S2S	Subseasonal-to-Seasonal	
SBES	Social, Behavioral, and Economic Sciences	
SENSR	Spectrum Efficient National Surveillance Radar	
ShiELD	System for High-resolution Prediction on Earth-to-Local Domains	
SLA	Service-Level Agreements	
SPC	Storm Prediction Center	
SSP	Social Science Program	Sub-program
STEM	Science, Technology, Engineering, and Math	
STRONG	Social Science Transitions from Resarch to Operations: An NSF and NOAA Grant	
TC	Tropical Cyclone	
UAS	Unmanned Aircraft Systems	
UFS	Unified Forecast System	
UMBC	University of Maryland Baltimore County	
UMD	University of Maryland	
USCLIVAR	United States Climate Variability and Predictability Program	
VORTEX-SE	Verification of the Origins of Rotation in Tornadoes Experiment Southeast	
The Weather Act	The Weather Research and Forecsting Innovation Act of 2017	
WPO	Weather Program Office	New name as of 4/3/2020


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