Annual Accomplishments

OFFICE OF WEATHER AND AIR QUALITY
National Oceanic and Atmospheric Administration

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

OFFICE OF WEATHER AND AIR QUALITY

National Oceanic and Atmospheric Administration

Office of Weather and Air Quality Annual Accomplishments FY2018 | April 2019
Director: John Cortinas, Ph.D.
Deputy Director: Kandis Boyd, Ph.D.

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From front row, left: Kandis Boyd[P], Chandra Kondragunta[P], John Cortinas[P], Mark Vincent[P], John Opatz*, Jordan Dale*, DaNa Carlis[P], Bradford Johnson*[P]

Not pictured: Richard Fulton, Johnna Infanti*[P], and Matthew Mahalik*
Affiliates are denoted with (*) and doctorates are denoted with ([P]). Photo Credit: Laura Wilson, NOAA (October 2018).

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Notes: (1) Unless otherwise noted, all images are courtesy of NOAA or researchers funded by NOAA. (2) Every effort was made to compile accurate data and information; OWAQ regrets any errors or omissions. (3) Narratives about current or intended transitions into operations are denoted with .

ON THE FRONT AND BACK COVERS: Lightning Strike. Image credit: Mary Murnan for NOAA's National Severe Storms Laboratory (June 2018).

Annual Accomplishments

FY2018 >>

LETTER FROM THE DIRECTOR

John Cortinas, Ph.D.
Director, Office of Weather and Air Quality
NOAA's Office of Oceanic and Atmospheric Research
April 2019

The Office of Weather and Air Quality was directed to fund and transition world-class research. We did.

NOAA's Office of Weather and Air Quality (OWAQ) is entrusted with finding, funding, and fostering collaborative weather and air quality research. Together, the OWAQ team and partners find answers to our Nation's most pressing questions about tropical cyclones, hazardous weather, flooding, air quality, and human responses to these risks, among many other research areas.

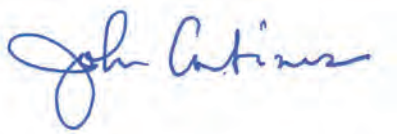
OWAQ has undergone transformative growth this year to align with NOAA priorities, execute a larger budget, manage award processes efficiently, and work collaboratively across the weather enterprise to advance weather and air quality research and transitions. As always, extraordinary teamwork and dedication made our accomplishments possible. In particular, I acknowledge our team and partners for:

- Increasing the number of funding awards from **62 to 84**, a 27% increase over FY2017.
- Increasing Federal employees from **5 to 8**, a 60% increase over FY2017.
- Increasing the contract staff from **5 to 11**, a 120% increase over FY2017.
- Shepherding a budget increase from **$24.1 million to $37.1 million**, a 54% increase over FY2017.
- Serving as NOAA's Office of Oceanic and Atmospheric Research lead for executing congressional directives.

As you will read in the pages that follow, our team and partners also addressed the difficult research questions whose answers help us understand and predict our weather. I acknowledge them for scientific accomplishments that ranged from using drones to improve National Weather Service (NWS) models for storm intensification[1] to using satellite data to improve tropical cyclone prediction.[2]

The Office of Weather and Air Quality was directed to fund and transition world-class research: We did that, and, with our team and partners, will do still more.

Sincerely,



ANNUAL ACCOMPLISHMENTS

Executive Summary

In 2018, fourteen weather and climate disaster events across the United States (U.S.) caused losses in excess of $1 billion each. That mix of drought, severe storms, tropical cyclones, wildfire, and winter storm events resulted in the deaths of 247 people and had significant economic effects.[3] National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) analysts report that weather alone can cause the gross domestic product in the U.S. to vary by as much as $1.3 trillion annually.[4] By fostering weather research related to high-impact events, and by focusing on research that enables effective communication of the risks, the Office of Weather and Air Quality (OWAQ) is supporting the world-class weather and air quality research that makes it possible to save lives, reduce property damage, and enhance the national economy.

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

MISSION: 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.

OWAQ discovers, develops, and transitions products, tools, and services for world-class weather and air quality research by finding, funding, and fostering collaborative research within NOAA's research laboratories and across the weather enterprise (i.e., NOAA, other Federal agencies and entities, state and local governments, academia and other not-for-profits, and the private sector). Accomplishments in fiscal year 2018 (FY2018) supported each of the office's four goals.

Goal 1. OWAQ improved effective communication of weather information to strengthen decision-making and forecasting abilities through a mix of assessments and studies by enhancing the integration of social, behavioral, and economic science (SBES) into weather research and development[5] and integrating SBES research findings into weather enterprise applications.

In particular, OWAQ supported the National Academies of Sciences, Engineering, and Medicine study on integrating SBES into the weather enterprise, then began addressing the identified challenges and proposed solutions. OWAQ also expanded funding of research with a social, behavioral, and/or economic component in FY2018 by incorporating social science into OWAQ's yearly funding calls; funding social science through National Science Foundation (NSF) supplementals called the Social Science Transitions from Research to Operations Program: A NSF and NOAA Grant; and developing a special economics research effort.

OWAQ also employed SBES research-informed practices for internal and external communication via the office's website, social media, and presentations at major conferences.

Goal 2. OWAQ and partners advanced models and forecast tools to produce the best weather forecasts and warnings to build a Weather-Ready Nation by advancing the development and implementation of NOAA's Unified Forecast System; beginning to advance Subseasonal-to-Seasonal forecasts; and improving severe weather prediction capability.

In particular, OWAQ and partners coordinated expertise across the weather community, including academia, the private sector, and government officials, while also serving NOAA as an expert on the Weather Research and Forecasting Innovation Act of 2017 as the Office of Oceanic and Atmospheric Research's (OAR) Weather Portfolio Steward. OWAQ and partners also advanced models and forecast tools by funding researchers focusing on increased resolution, data assimilation, physics upgrades, and other related priorities. Among the models

13 Percentage of projects improving operational models

23 Number of peer-reviewed publications

53 Percentage of projects increasing readiness level

25 Percentage of transition projects with signed transition plans

5 Research and development results transferred into operations

19 Percentage of projects that include social, behavioral, and/or economic science research

FIGURE 1. The Office of Weather and Air Quality by the Numbers. Image credit: Office of Weather and Air Quality Annual Operating Plan FY2018.

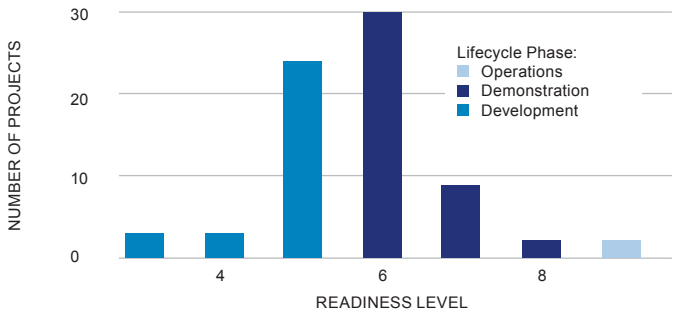


FIGURE 2. Distribution of Projects by Readiness Level in FY2018 (Active Projects; Levels Range from Basic Research (1) to Deployment (9).

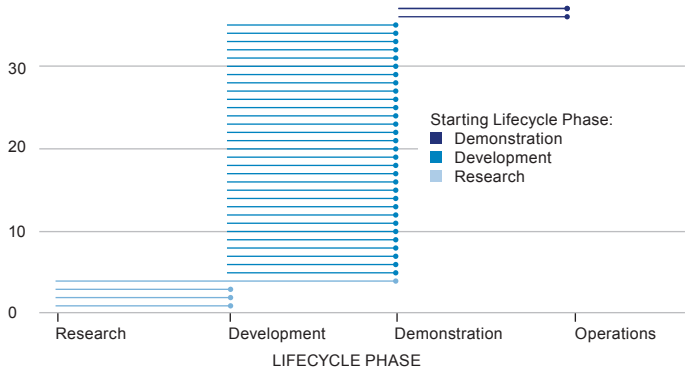


FIGURE 3. Shifts in Readiness Level Based on Starting Lifecycle Phase for FY2018 (Active Projects).

and forecast tools advanced, OWAQ supported funding for the Verification of the Origins of Rotation in Tornadoes Experiment - Southeast (VORTEX-SE) and expanded the OAR modeling inventory.

Goal 3. OWAQ and partners effectively and efficiently managed the advancement and transition of weather research into societal applications by advancing the development and transition of weather research to operations; ensuring operations and management processes were well-documented, maintained, and refined; and responding in a timely and effective manner to NOAA's Congressional mandates.

OWAQ and partners employed research-based practices for transitioning research to operations, such as thinking ahead to the transition with the initial proposal and progress reports; partnering researchers and operators; and following NOAA's process for transition plans.

OWAQ advanced and transitioned weather research across the portfolio. Among other activities, OWAQ transitioned to algorithms, wrote transition plans, and moved two projects into operations (see also Figures 2 and 3).[6]

Goal 4. OWAQ developed and supported a diverse and inclusive work environment that promoted equal access to the opportunities OWAQ offers by recruiting and maintaining a diverse and highly qualified workforce; promoting and enhancing the inclusion of OWAQ's diverse workforce; and integrating and promoting diversity and inclusion as a core consideration throughout OWAQ's funding mechanisms.

In particular, OWAQ developed and supported a diverse and inclusive work environment by increasing the number of Federal employees by 21% in FY2018 (5 to 8 employees) and increasing contract staff by 55% in FY2018 (5 to 11 contractors) while considering gender, race/ethnicity, generational, and educational balances (see also Figures 5 and 6).

OWAQ and research partners supported the Department of Commerce's commitment to increasing the participation of minority-serving institutions (i.e., Historically Black Colleges and Universities, Hispanic-serving institutions, Tribal colleges and universities, and Alaskan Native and Native Hawaiian institutions), and institutions that work in under-served communities. Moreover, some grantees reported on a focus on diversity and inclusion, especially for professional development and training.

Transitioning World-Class Research into Operations. To meet these goals while preparing for OWAQ's new responsibilities, new structures were established: the team grew; process efficiencies were introduced; redundancies were eliminated; and new partnerships were developed. Supported by these new structures, OWAQ established working groups; prepared congressional reports; built the OAR modeling inventory; hosted multiple workshops; and issued and managed Federal funding opportunities (see Figure 4).

The accomplishments above and in the pages that follow are the product of OWAQ's partnerships and OWAQ's focus on the research and development activities that led to demonstrations in NOAA's testbeds. In these testbeds, project outcomes such as new observing systems and data products, improved data analysis techniques, and better statistical or dynamic models and forecast techniques are presented to operational forecasters and evaluated for potential future implementation in the National Weather Service (NWS) forecast offices at the local, regional, and/or national center levels. These improvements create a Weather-Ready Nation informed by world-class weather research.

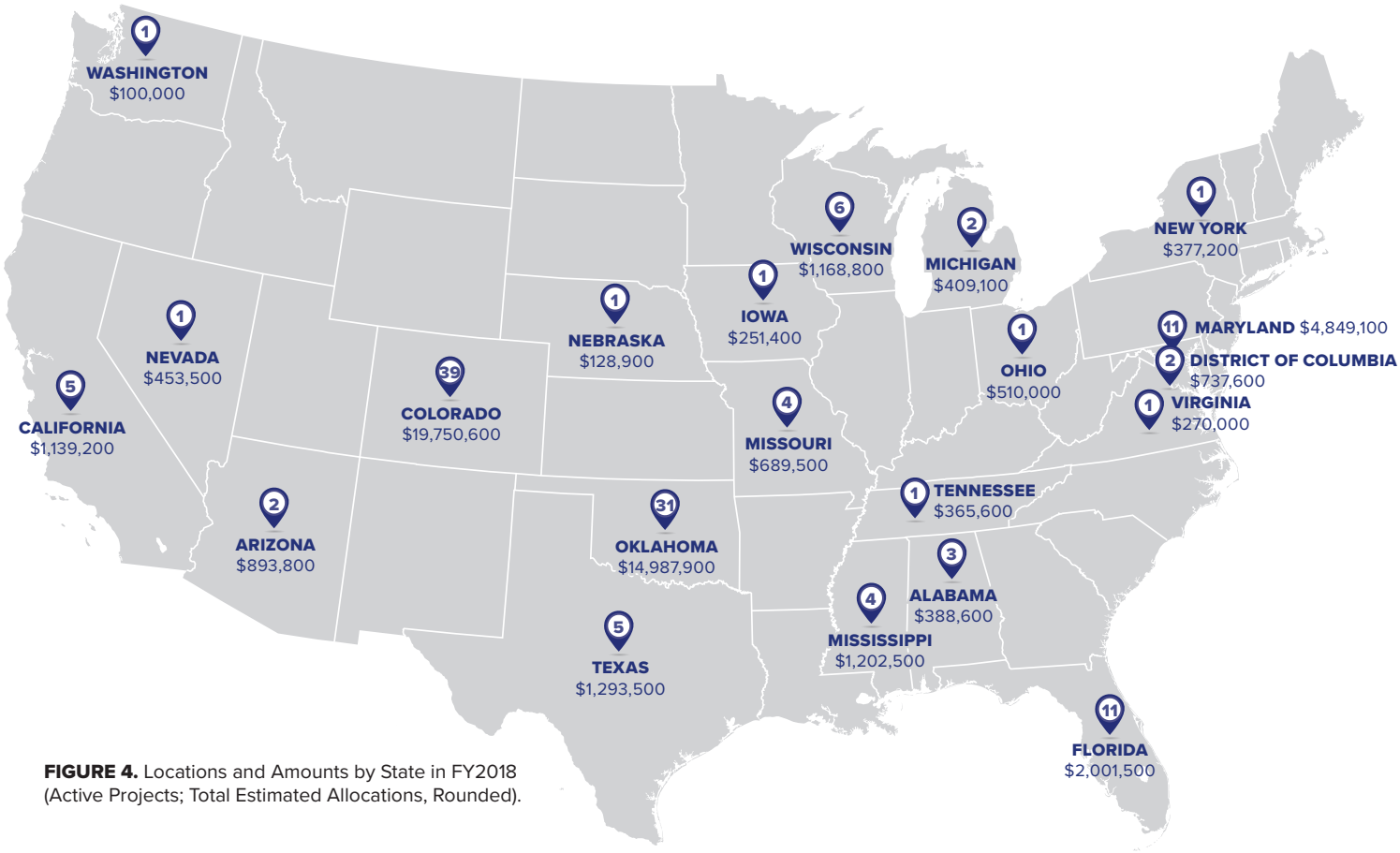


FIGURE 4. Locations and Amounts by State in FY2018 (Active Projects; Total Estimated Allocations, Rounded).

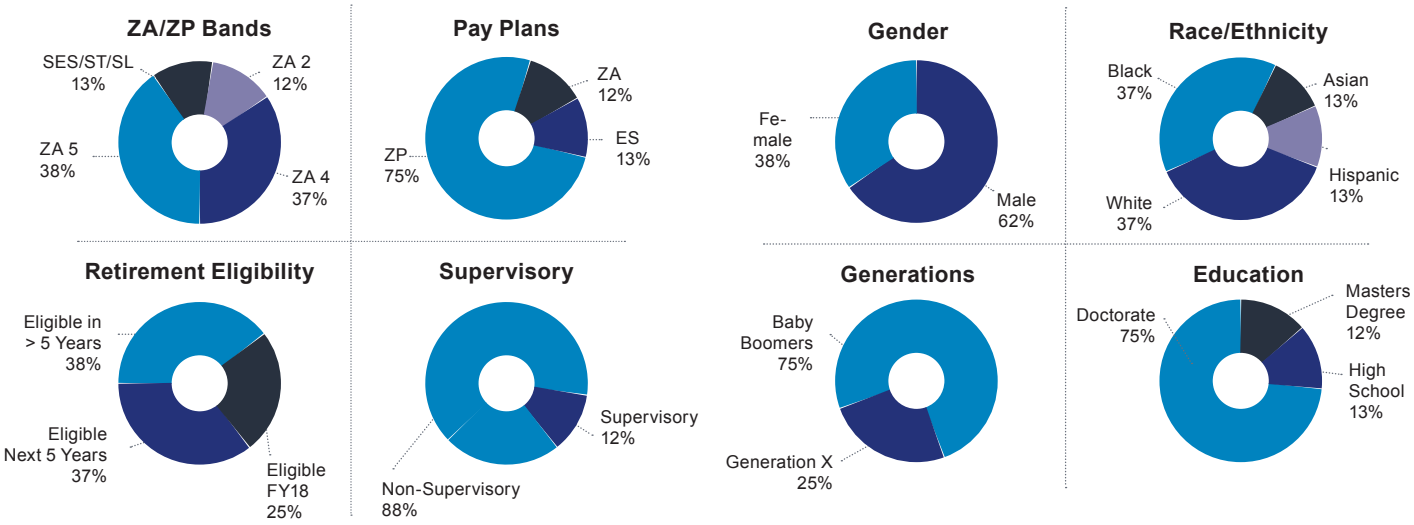


FIGURE 5. OWAQ Workforce Profiles (Federal employees at the end of FY2018).

FIGURE 6. OWAQ Diversity Profiles (Federal employees at the end of FY2018).

Tropical Cyclones

(includes Hurricanes, Typhoons, and Cyclones)

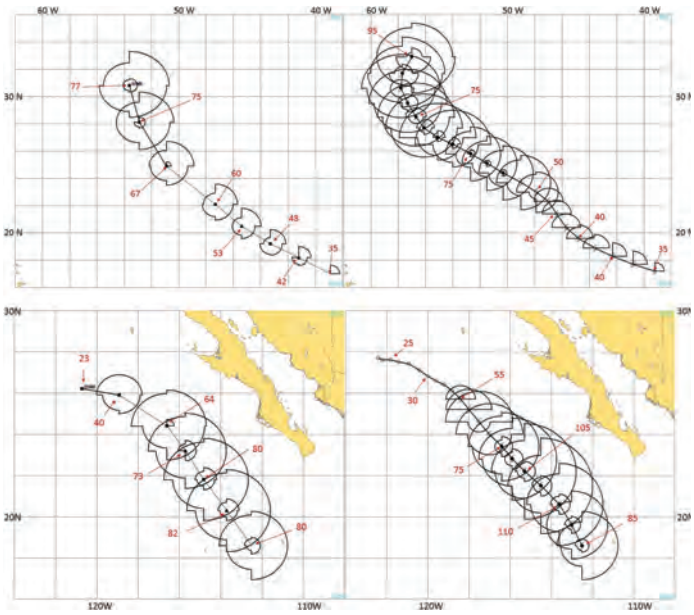


FIGURE 7. Forecasts for Hurricanes (top) Edouard (0000 UTC 12 Sep 2014) and (bottom) Linda (0000 UTC 8 Sep 2015) with (right) Corresponding Best Tracks. To improve the aesthetics and readability of the figures, only the 34- and 64-kt wind radii are shown, the latter being shown as inner concentric rings when the intensity exceeds 64 kt. Note that intensity biases affect the forecast of wind radii with under- (over-) forecasts of intensity corresponding to slightly smaller (larger) 34-kt wind radii. Image credit: Figure 8 of Knaff, J.A., C.R. Sampson, and G. Chirokova. 2017. "A Global Statistical–Dynamical Tropical Cyclone Wind Radii Forecast Scheme." Weather Forecasting, 32, 629–644, https://doi.org/10.1175/WAF-D-16-0168.1. © American Meteorological Society. Used with permission.

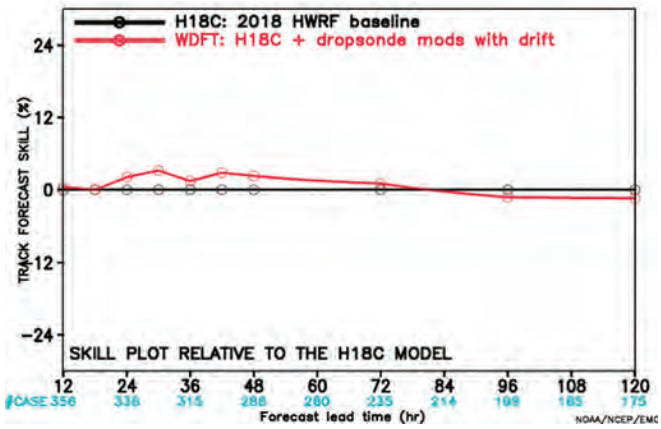


FIGURE 8. Change in Track Error (expressed as percent improvement) as a Result of Assimilating Drift-Estimated Dropsonde Data. Image credit: Jason Sippel.

Tropical cyclones develop when a tropical storm intensifies and winds reach 74 miles per hour (119 kilometers per hour) and are known variously as hurricanes (Atlantic and Eastern Pacific Oceans), typhoons (Western Pacific), and cyclones (Indian Ocean).[7] The impacts of tropical storms can be devastating; storm surge can cause deaths and devastating property loss ranging from damaged roads and bridges to destroyed homes and businesses.

In 2018, there were fifteen named storms in the North Atlantic, including eight hurricanes and two major hurricanes.[8] The two major hurricanes, Florence and Michael, caused approximately $49 billion in combined damages,[9] including the damage to communication, transportation, and utility infrastructures as a result of heavy rains, strong winds, and waves.

Consistent with OWAQ's goals and objectives, research priorities for tropical cyclones include:[10]

(1) Improve operational analysis of the surface wind field.
(2) Identify new applications of ensemble modeling systems for track, intensity, and structure forecasting.
(3) Improve tropical cyclone intensity guidance.
(4) Improve guidance for tropical cyclone genesis.
(5) Advance coastal inundation modeling and/or applications, visualization, and/or dissemination technology.
(6) Develop probabilistic wave height forecasts.
(7) Apply and 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.

In FY2018, approximately 1 out of every 10 projects funded by OWAQ contributed to tropical cyclone research.

Improving Tropical Cyclone Intensity Forecast Models | Joint Hurricane Testbed

Galina Chirokova & John Kaplan | Colorado State University-Cooperative Institute for Research in the Atmosphere; NOAA's Atlantic Oceanographic and Meteorological Laboratory [see Figure 7]

This project proposed to complete a number of upgrades to the operational statistical hurricane intensity models, which have provided operational intensity guidance for the last five years through the addition of a tropical cyclone wind structure based predictor or combination of predictors to the Statistical Hurricane Intensity Prediction Scheme, the Logistic Growth Equation Model, the multi-lead time probabilistic Rapid Intensification Index, and the global Rapid Intensification Index.

Accounting for Dropsonde Drift to Improve Tropical Cyclone Forecasts | Joint Technology Transfer Initiative

Jason Sippel | NOAA's Atlantic Oceanographic and Meteorological Laboratory [see Figure 8]

A fundamental problem for hurricane assimilation is that dropsondes capture the release point instead of the observation point. This leads to small errors in the environment around a storm, which can result in unacceptable errors at the inner core of a storm. Researchers conducted a large retrospective analysis of over 300 cases with data that has been processed by

a newly developed algorithm to account for dropsonde drift. Consideration of dropsonde drift and use of all dropsonde data will have a significant positive benefit on forecasts through operational use in the National Centers for Environmental Prediction Global Forecast System and the Hurricane Weather Research and Forecasting regional model.

Improving the Accuracy of Hurricane Intensity Forecasts | Joint Hurricane Testbed

Anthony Wimmers | University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies

To improve the accuracy of hurricane intensity forecasts, researchers worked to develop a new computer model based on microwave satellite imagery that would provide diagnostic and forecast guidance prior to and during hurricane eyewall replacement cycles. Results could include integration of the model into SHIPS and possible transition to NOAA's National Hurricane Center (NHC). Ongoing work was funded by a Joint Polar Satellite System Risk Reduction grant to integrate the model into a real-time data processing environment for the NHC, the Central Pacific Hurricane Center, and the Joint Typhoon Warning Center.

Using Satellite Data to Improve Tropical Cyclone Prediction | Joint Hurricane Testbed

Chris Rozoff | University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies

To improve tropical cyclone prediction, researchers sought to provide a computationally efficient forecasting tool to advance the current state-of-the-art hurricane rapid intensification forecast technique by adding microwave satellite imagery data. Researchers created a large climatological passive microwave dataset containing virtually all satellite passes over Atlantic and Eastern Pacific Tropical Cyclones at the 18.7, 36.5, and 89 GHz channels. Using these data improved tropical cyclone intensity predictions, especially Rapid Intensification, which will be valuable as part of an improved suite of statistical-dynamical forecast guidance available at the National Hurricane Center.

Hazardous Weather

(includes Thunderstorms, Severe Wind and Hail Storms, Tornadoes, Heavy Rainfall, Winter Weather, and Flooding)

The term "hazardous weather" is usually applied to local, intense, often-damaging storms such as thunderstorms, severe wind and hail storms, and tornadoes, but it also can be used to describe heavy rainfall, winter weather such as heavy snow and ice, and flooding such as coastal, inland, and flash flooding.[11] Annually, the U.S. is struck by 100,000 thunderstorms, 10,000 severe thunderstorms, 5,000 floods or flash floods, and 1,000 tornadoes.[12] About 90 percent of all presidentially declared disasters are hazardous-weather-related, representing 500 deaths and nearly $15 billion in damage per year.[13]

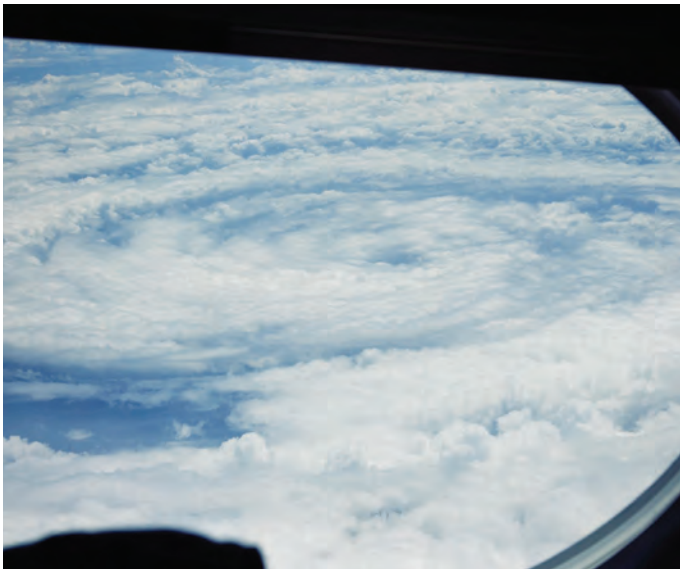


FIGURE 9. Eye of Hurricane Edouard Taken from NOAA's Gulfstream IV Aircraft. Image credit: Ching-Hwang Liu for NOAA's Atlantic Oceanographic and Meteorological Laboratory (September 2002).

Consistent with OWAQ's goals and objectives, research priorities for hazardous weather include:[14]

(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) 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) Identify and validate new or improved ways of enhancing forecaster use of probabilistic precipitation or ice accumulation short-range and medium-range forecasts.
(5) Identify and validate new or improved methods, observations, decision-support tools, and models to improve understanding or evaluate forecast performance of extreme precipitation events.
(6) Improve numerical weather prediction modeling through data assimilation, post-processing, and verification capabilities.
(7) Improve extreme precipitation forecasting.
(8) Apply and 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.

In FY2018, approximately 5 out of every 10 total projects funded by OWAQ contributed to hazardous weather research.

Understanding Simulated Storm Updrafts and Rotation to Improve Severe Hail Forecasting | Hazardous Weather Testbed

Israel Jirak | National Weather Service-Storm Prediction Center [see Figure 10]

Researchers sought to improve severe hail forecasting through targeted information extraction from convection-allowing model forecasts and by objective verification using radar-derived hail size estimates. Two new products were made available to NWS forecasters as operational guidance in forecasting severe hail using the HiRes Window and High-Resolution Rapid Refresh runs: (1) Hourly minimum updraft helicity (2-5 km AGL) to identify left-splitting supercells, which can be prolific hail producers; and (2) Hourly maximum updraft speed (below 100 mb) to better estimate storm intensity and potential hail size.

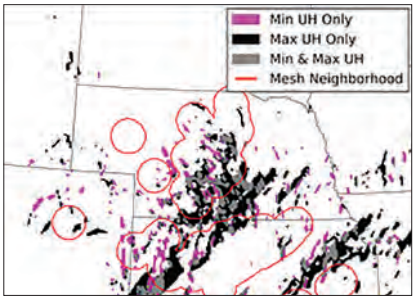


FIGURE 10 (left). Spatial Contribution of 2–5 km AGL Minimum (magenta), Maximum (black), and Full (gray) 24-h UH to Severe (≥ 29 mm) Hail MESH 40 km Neighborhoods (red circles). Data from 0000-UTC initialized NSSL-WRF on 08 May 2016. Image credit: Provided by Israel Jirak.

Using Drones to Improve Severe Storm Forecasts | Joint Technology Transfer Initiative

Steve Brooks | University of Tennessee [see Figures 11 and 12]

To improve severe storm forecasts, researchers used the existing hyperspectral and thermal imaging instruments on a University of Tennessee aircraft—and developed those same instruments onto a University of Tennessee drone—to assess the Lifted Index of near-surface air as a precursor to deep convection. Researchers performed full-flight testing of the Unmanned Aerial Vehicle equipped with the new sensors. This progressed resolution from 1 meter per pixel to 2 centimeters per pixel, which improves the input data in NWS models and leads to better severe storm forecasts.

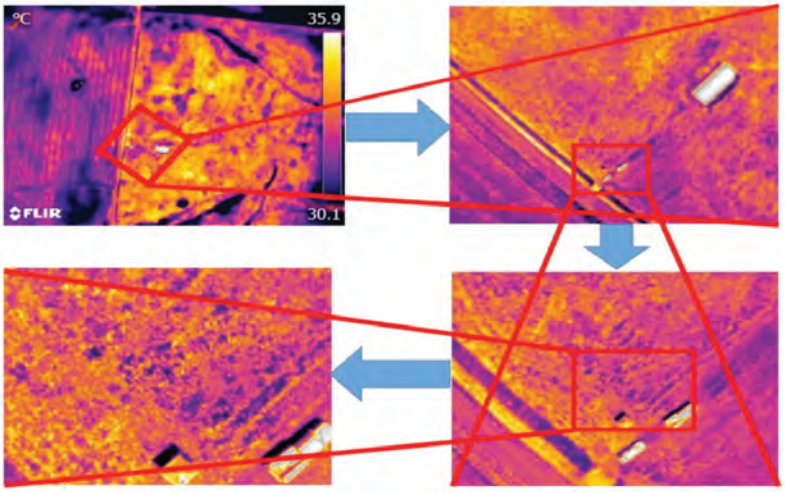


FIGURE 11. Improved Resolution of Hyperspectral and Thermal Imaging Using an Unmanned Aerial Vehicle. Image credit: Brooks Presentation, https://bit.ly/2FzSXc3. © American Meteorological Society. Used with permission.

FIGURE 12. Image of the Team at the University of Tennessee in Front of the Research Aircraft. Image credit: Brooks Presentation, https://bit.ly/2FzSXc3 (June 2018). © American Meteorological Society. Used with permission.

Using Machine Learning to Improve Quantitative Precipitation Forecasts (QPFs) | Joint Technology Transfer Initiative

Russ Schumacher | Colorado State University

Using machine learning techniques, researchers developed a probabilistic forecast of extreme rainfall systems to provide improved guidance to the forecasters of the Weather Prediction Center (WPC). Researchers improved quantitative precipitation forecasts (QPFs) by testing machine learning techniques in the 2017 Flash Flood and Intense Rainfall experiment. The WPC will be able to provide communities with improved QPFs, allowing them to better prepare for dangerous flash floods.

Improving Probability Information about Particular Hazards | Hazardous Weather Testbed

Kristin Calhoun, Wayne Feltz, Lans Rothfusz, & Michael Pavolonis | University of Oklahoma; University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies; National Severe Storms Laboratory; National Environmental Satellite, Data, and Information Service

Researchers integrated satellite, multi-radar, lightning (future capability), and environmental data to determine the probability of a given storm producing severe weather in the next sixty minutes. This project contributed to improving the overall probability information about particular hazards (e.g., hail, tornado).

FIGURE 13 (right). A Colorado Rainbow and Rainshaft. Image credit: Jared Rackley, Weather in Focus Photo Contest 2015 (May 2014) from NOAA's Photo Library.

Flooding *(Hydrological)*

Flooding is the result of an overflow or inundation from a river or other body of water that causes or threatens damage. Coastal storms, heavy rain, and melting snow (addressed in previous sections) are all potential causes. When flooding is on coastal lands, it is termed "coastal inundation" and, 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.

Flooding can endanger life, property, and economies. In 2016, societal impacts included 126 fatalities and $10.9 billion in damage from flash floods and river floods.[15] From 1980–2018, there were 29 billion-dollar flooding events in which 543 lives were lost and the average flood event cost $4.3 billion.[16]

Consistent with OWAQ's goals and objectives, research priorities for flooding include:[17]

(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) Improve water prediction capabilities to include efforts to enhance hydrologic prediction through improved data assimilation and model extension for hydrological data sets.
(4) Focus on advancements leading to improved surface-based or airborne-based observing capabilities of snow depth (snow water equivalent) and soil moisture.
(5) Apply and 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.

In FY2018, approximately 2 out of every 10 total projects funded by OWAQ contributed to hydrological research priorities.

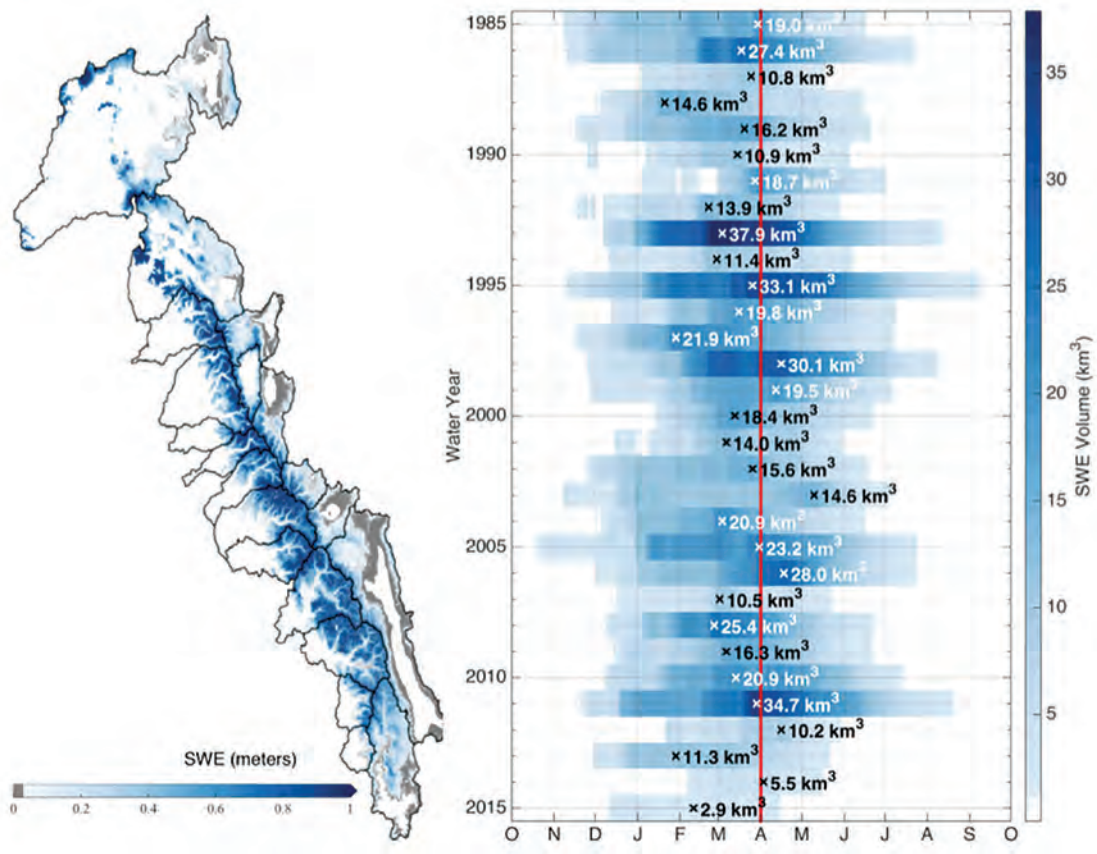


FIGURE 14. Left panel: Map of 31-Year Climatology of Snow-Water Equivalents (SWE; in meters) over the Sierra Nevada. Right panel: Visualization of Daily Range-Wide SWE (in km3) Including the Peak Annual Value and Its Day of Occurrence (red line corresponds to 1 April). Image credit: Provided by Konstantinos Andreadis.

Using Radar to Improve Flash Flood Warnings | Hydrometeorology Testbed

Jonathan Gourley | NOAA's National Severe Storms Laboratory

To improve flash flood warnings, researchers tested and transitioned a set of experimental radar-based flash flood tools and products for use by NWS weather forecast offices. These improved flash flood watches and warnings for the near-term (0-6 hour forecast period), so the Flooded Locations and Simulated Hydrographs software was successfully transitioned to the National Centers for Environmental Prediction with the latest Multi-Radar/Multi-Sensor deployment.

Improving Prediction of Snowmelt Impacts | Snowpack and Soil Moisture

Konstantinos Andreadis | University of California Los Angeles [see Figure 14]

To improve the National Water Model's (NWM) ability to reproduce snow conditions and to predict streamflow in snow-dominated river basins, researchers will use evaluation and error diagnosis with a state-of-the-art, observation-based dataset. Researchers will provide to the NWM team the datasets with improved parameterizations of the NWM, a set of simulation datasets along with output evaluation metrics, and the observational datasets of the snow-water equivalent reanalysis with uncertainty estimates as well as the observational datasets (from Landsat, MODIS and VIIRS) used in their derivation.

Improving the Representation of Cloud and Precipitation Microphysics in Numerical Forecast Simulations | Hydrometeorology Testbed

David Kingsmill | University of Colorado-Cooperative Institute for Research in Environmental Sciences

This project sought to improve the representation of cloud and precipitation microphysics in numerical forecast simulations of coastal orographic precipitation along the West Coast. Extreme precipitation can lead to devastating flooding and debris flows in the coastal mountain regions during periods of enhanced moisture flow associated with atmospheric rivers. Although researchers were not able to implement and test any modifications to the Ferrier-Aligo (F-A) microphysics scheme in an operational setting during the project, they developed recommendations for improving the F-A scheme to better represent orographic warm rain. Each of these improvements is a step toward improved forecasts.

Using Velocity Data to Form a Better Picture of Flash Flooding | Joint Technology Transfer Initiative

Daniel Wasielewski | Cooperative Institute for Mesoscale Meteorological Studies [see Figure 15]

Researchers sought to improve hydrologic forecasting in the new National Water Model (NWM) with the installation of fourteen stream radars on cables or bridges across rivers at

FIGURE 15. Stream Radar in Mill Creek, Oklahoma. Image credit: Jorge Duarte (April 2017).

the pre-determined, high-priority locations. In support of the NWM, during a flash flood event stream radars can complement the existing U.S. Geological Survey stream gauge network and capture instances in which water levels are the same but the velocity varies.

Improving Streamflow Predictions | Snowpack and Soil Moisture

Heather Reeves, Mimi Hughes, and David Gochis | University of Oklahoma; Cooperative Institute for Research in Environmental Sciences and National Center for Atmospheric Research

This research advanced the Spectral Bin Classifier, which provides three-dimensional hydrometeor phase diagnosis and estimates of the liquid-water fraction of falling precipitation. Researchers are transferring this product from a research version of the code to a real-time experimental version as a part of the Multi-Radar/Multi-Sensor (MRMS) System at NOAA's National Severe Storms Laboratory. Researchers also are investigating the feasibility and value of incorporating dual-polarized radar information for refining the algorithm's output. Post-testing, the product will be transitioned to the operational version of MRMS running at the National Centers for Environmental Prediction, pending NWS acceptance.

Air Quality

Although air quality has improved following the passage of the Clean Air Act in 1970, in many areas of the country the public is still exposed to unhealthy levels of air pollutants and sensitive ecosystems are damaged by air pollution. Both wildfires in the West and high surface ozone episodes during heat waves in the East contribute to poor air quality. NOAA works with the Environmental Protection Agency, state and local air quality agencies, academia, and the private sector to provide an air quality forecast capability for the Nation called the National Air Quality Forecasting Capability.

Consistent with OWAQ's goals and objectives, research priorities for air quality include:[18]

(1) Development and evaluation of high-resolution (1-4 km) air quality forecast capabilities that are consistent with NOAA weather forecast models at these resolutions.
(2) Incorporation of the Finite Volume Cubed-Sphere Dynamical Core (FV3) model-driven meteorological predictions in the National Air Quality Forecasting Capability with on-line coupling in the near future.
(3) Improved spatial and temporal estimates of anthropogenic and natural pollutant emissions.

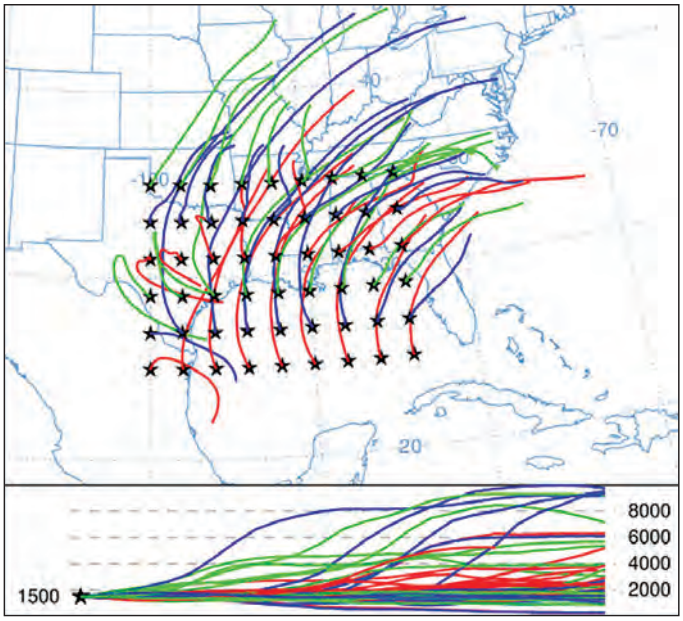


FIGURE 16. Forward 24h Trajectory Matrix Forecast at 1500 m Above Ground Level Using the NAM Meteorological Data. Image credit: Creative Commons License, https://doi.org/10.1016/j.envsoft.2017.06.025

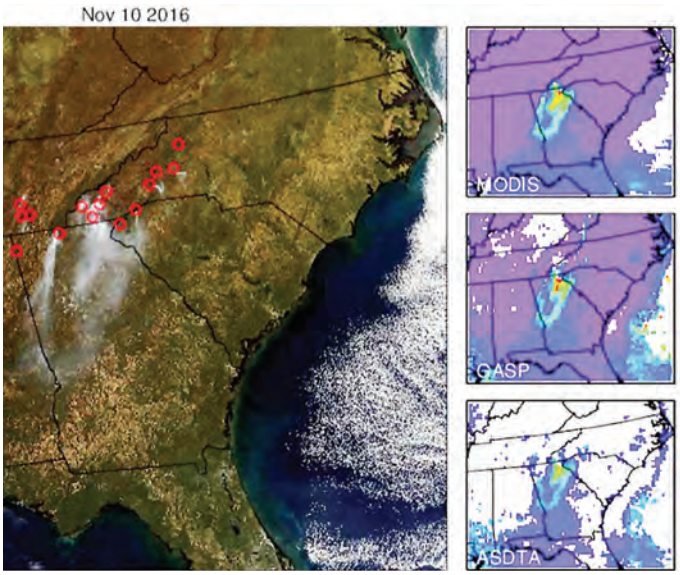


FIGURE 17. Observed Fire Events in Southeastern U.S. on November 10, 2016. MODIS truecolor image is shown in left panel, and MODIS, GOES Aerosol/Smoke products, Automated Smoke Detection and Tacking Algorithm aerosol optical depths are shown in right panel. Red circles indicate locations of wildfires detected by the Hazardous Mapping System. Image credit: Provided by Tianfeng Chai.

(4) Exploration and quantification of the potential value of ensemble model approaches and post processing to operational air quality forecasting.
(5) Improved model representation in the FV3 model of physical/chemical processes for long range transport.
(6) Apply and 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.

In FY2018, approximately 1 out of every 10 projects funded by OWAQ contributed to air quality research priorities.

Assessing and Communicating Uncertainty in Modeled Transport, Dispersion, and Deposition of Hazardous Materials | Joint Technology Transfer Initiative

Barbara Stunder | NOAA's Air Resources Laboratory [see Figure 16]

In this project, researchers are improving deterministic approaches with products that assess and communicate uncertainty in the models of hazardous material transport, dispersion, and deposition. This serves emergency response applications as diverse as simulating atmospheric plumes from chemical releases, smoke from wildfires, or wind-blown dust.

Improving the Forecasts of Smoke from Wildfires | Air Quality

Tianfeng Chai | University of Maryland [see Figure 17]

This project seeks to provide a better smoke forecast by developing a Hybrid Single Particle Lagrangian Integrated Trajectory Model 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: (1) Transitioning the inverse system code to the NOAA operational environment, if possible; (2) Modifying the code interface to read near-real-time Geostationary Satellite aerosol/smoke products; and (3) Evaluating the smoke forecasts using the optimally estimated emissions.

Improving Air Quality Prediction | Air Quality

Irina Djalalova | NOAA's Physical Sciences Laboratory and the Cooperative Institute for Research in Environmental Sciences at the University of Colorado [see Figure 18]

This project proposed to provide improved accuracy of particulate matter (PM2.5) and surface ozone air quality forecasts provided to the public. An initial beta-version of ozone post-processing code was delivered to the National Centers for Environmental Prediction (NCEP). An updated version was delivered to NCEP that included site-specific weighting of ozone forecasts. In addition, an updated version of the post-processing code that provides improved skill at forecasting extreme events for both ozone and PM2.5 was developed, tested, and evaluated against the NCEP Community Multiscale Air Quality forecasts. Based on this testing, NCEP has approved the new ozone post-processing scheme, as well as updates to the PM2.5 scheme, for the next operational model implementation upgrade.

FIGURE 18 (right). This image shows a 16-day time-series of observed and forecast PM2.5, spatially averaged over 905 sites in the western third of the U.S. Early in the time period there were numerous fires burning in Washington and Oregon states and western Canada, leading to high PM2.5 values during the first 5 days of August. Whereas the raw CMAQ forecasts (red line) reached PM2.5 values as high as those observed during this period, the original KFAN method (blue dashed line) predicted values that were much too low, as it did not find a sufficient number of good analogs with high PM2.5 values. In contrast, the new KFAN method modified for extreme events (solid blue line) does a much better job of matching the observed high PM2.5 values. Image credit: Provided by Irina Djalalova.

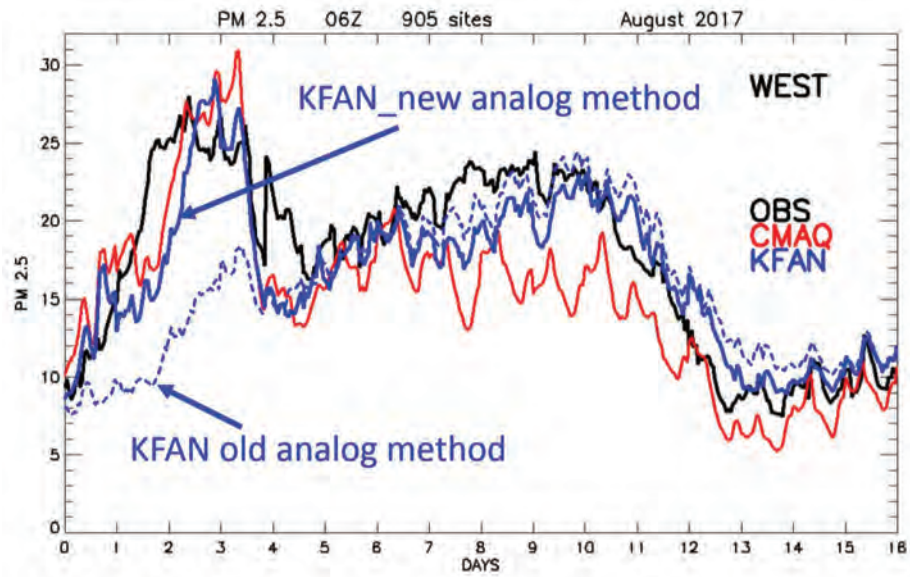


FIGURE 19. Fire Suppression Operations for the Cold Spring Fire Near Nederland, Colorado. Image credit: Steve and Susan Williams, NOAA's Earth System Research Laboratory (August 2016).

Interdisciplinary Research

Interdisciplinary research is integrating knowledge and methods from different disciplines and synthesizing approaches. OWAQ interdisciplinary themes include, but are not limited to:

Uncertainty, including understanding and messaging of probabilistic hazard information. The OWAQ team and partners coordinate social, behavioral, and economic science research needs; determine approaches to translating social, behavioral, and economic science research into application; and learn from the operational community to understand the next research challenges (facilitated by the Social Science Program). Similarly, the OWAQ team and partners support multiple-hazard research across severe weather tropical cyclones, precipitation extremes, air quality, flash flooding, hydroclimate extremes, and other hazards to support NOAA's Weather-Ready Nation initiative and build natural hazard resilience in communities. This is possible with a next-generation severe weather watch and warning framework that is modern, flexible, and designed to communicate clear and simple hazardous weather information that serves the public (facilitated by the Forecasting a Continuum of Environmental Threats (FACETs) paradigm).

Timescales, including Subseasonal-to-Seasonal research. Subseasonal-to-Seasonal (S2S) research focuses on baseline understanding of predictability; advancement of community-driven NOAA modeling initiatives; and increasing the utility of multi-model ensembles for end users. This will fulfill the S2S (two weeks out to two years) requirements of the Weather Research and Forecasting Innovation Act of 2017 while emphasizing the models and components in NOAA's Unified Forecast System (UFS), the North American Multi-Model Ensemble, and ongoing multi-model ensemble efforts on the S2S timescale.

Data and models, including Weather-Water-Climate initiatives and the Joint Technology Transfer Initiative. The National Academy of Science reports, *Observing Weather and Climate From the Ground Up* (2009), and *The Future of Atmospheric Boundary Layer Observing, Understanding, and Modeling, Proceedings of a Workshop* (2018) underscore the importance of improved observations of the lower atmosphere (a region that is not particularly well-sampled by satellites) to better understand and predict specific, high-impact weather events. Programs such as the Joint Hurricane Testbed, Hydrometeorology Testbed,[19] and Joint Technology Transfer Initiative support development, testing, and evaluation of mature research that has the potential for improving NOAA's NWS operational capabilities, particularly in the areas of advancing numerical weather prediction capabilities that seamlessly integrate in the NOAA UFS, water prediction capabilities, and forecasting extreme precipitation and flooding events.

Consistent with OWAQ's goals and objectives, research priorities for interdisciplinary research include:[20]

(1) Identify and validate via quasi-operational testbed demonstrations new high temporal and spatial resolution in-situ and remotely-sensed observation datasets and dynamically consistent 3-D objective data-analysis techniques to provide the best state of the current environment.
(2) Apply and integrate relevant social and behavioral science methodologies into the above testbed priority areas to improve forecasters' use of convection-allowing/resolving data, techniques, and guidance.
(3) Apply and 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.

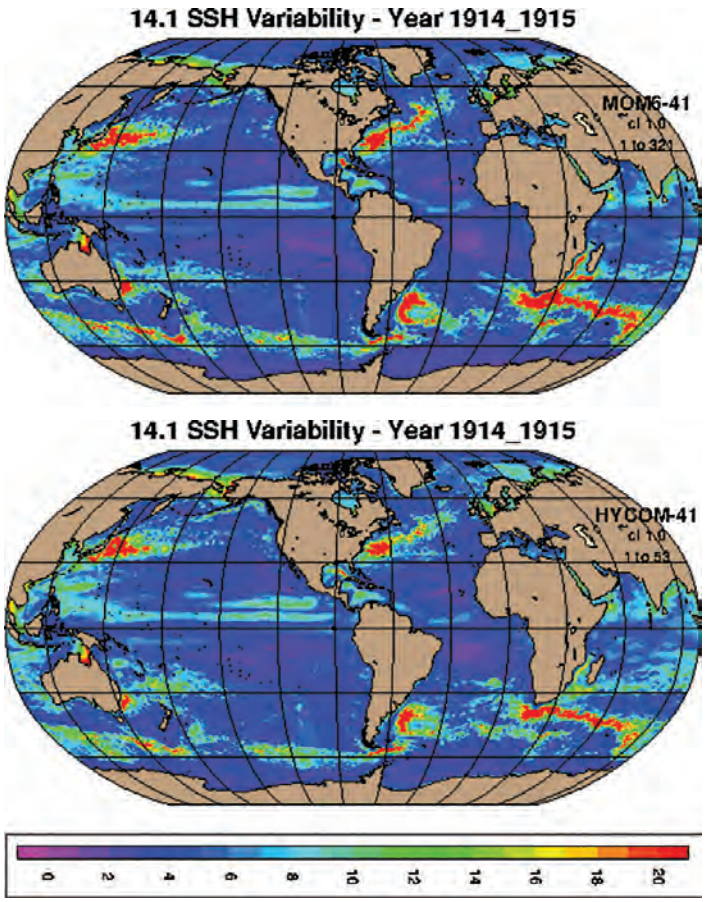


FIGURE 20. Comparison of HYCOM and MOM6 Models for Sea-Surface Height (SSH) variability. Image credit: Alan Wallcraft, Eric Chassignet, and Robert Hallberg via a collaboration between Florida State University and GFDL funded by the National ESPC.

In FY2018, approximately 2 out of every 10 projects funded by OWAQ contributed to those interdisciplinary research priorities.

Improving Understanding of Ocean Heat and Sea-Level Rise | Earth System Prediction Capability

Robert Hallberg | NOAA's Geophysical Fluid Dynamics Laboratory [see Figure 20]

In the latest version of the Modular Ocean Model (MOM6), researchers sought to enable eddy-resolving resolution runs (0.08 deg) and reported good preliminary results. This is an improvement over previous modeling which, at best, offered 0.1 degree resolution that was insufficient for understanding the details of all sizes of ocean eddies. Future work will incorporate internal wave drag parameterizations for tides, data assimilation preparations, and open boundary conditions (for nests).

Improving Guidelines for Expressing Uncertainty | Social Science Program

Susan Joslyn | University of Washington [see Figure 21]

A series of experimental studies conducted for this project revealed that forecast inconsistency causes a slight reduction in trust; however, the reduction in trust due to forecast inaccuracy is much greater. Moreover, inconsistency may give users important information about forecast uncertainty. Therefore, it is better to update the forecast even if it means inconsistency, especially if the forecaster thinks that the new information is likely to be more accurate.

Improving Subseasonal Forecasts of Extreme Hydrological Events | Joint Technology Transfer Initiative

Cristiana Stan | George Mason University

This research will provide a scientifically validated version of the Unified Forecast System with capabilities to run the computationally efficient ocean model MOM6 at 0.25 degrees global resolution. This supports improvements to subseasonal forecasts (lead times ranging from 15 to 45 days) that will allow stakeholders to better prepare for extremes in the hydrological cycle, such as the onset of drought conditions and heavy precipitation events.

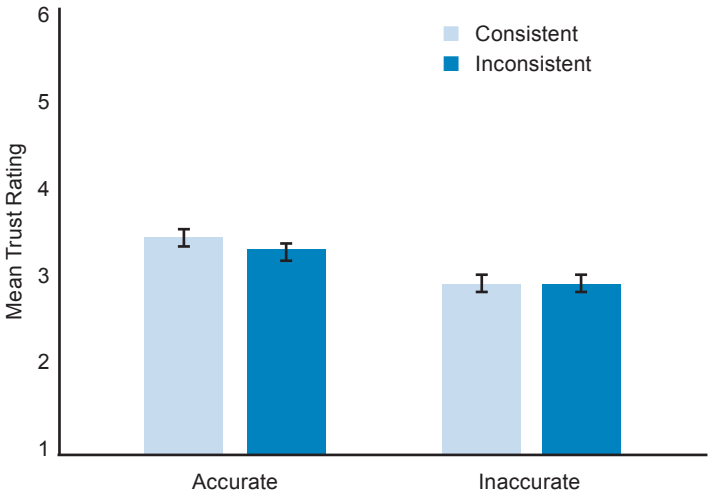


FIGURE 21. Experiment 1 Trust Ratings by Accuracy and Consistency. Image credit: Provided by Susan Joslyn.

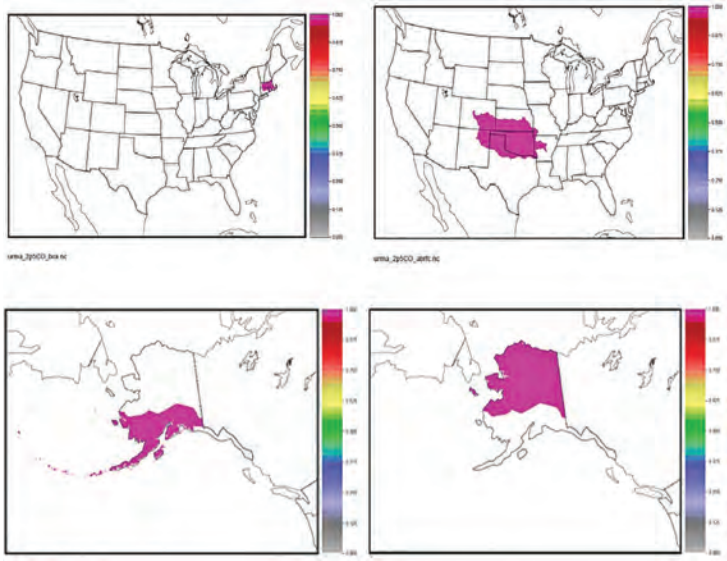


FIGURE 22. Model Evaluation Tools Enhanced with Shapefiles. Examples of masking regions generated from shapefiles by Dana Strom at the Meteorological Development Laboratory. Regions include the Massachusetts County Warning Area, the Missouri Basin River Forecast Center (MBRFC), and two regions in Alaska. Image credit: Provided by Tara Jensen.

Improving Research-to-Operations Transitions for FACETs | Joint Technology Transfer Initiative

Alan Gerard | NOAA's National Severe Storms Laboratory

This project continues the research-to-operations transition process for key aspects of the Forecasting a Continuum of Environmental Threats (FACETs) effort for convective hazards and will support the progress of Probabilistic Hazard Information towards initial operational implementation. FACETs is a proposed next-generation watch and warning framework that is designed to communicate clear and simple hazardous weather information to the public.

Improving the Use of Precipitation Forecasts | Hydrometeorology Testbed

Tara Jensen | National Center for Atmospheric Research [see Figure 22]

This project will integrate verification research with social science research to develop verification metrics and tools that improve forecasters' adoption, interpretation, and use of deterministic and probabilistic model guidance with a focus on convection-allowing guidance. Ultimately, researchers will identify a set of objective measures to be employed at the Hydrometeorology Testbed and, possibly, other testbeds such as the Hazardous Weather Testbed.

The Way Forward

Fulfilling the office's vision while meeting the needs of a Weather-Ready Nation requires ongoing innovation and a holistic view of our office's performance and our partners' needs. OWAQ delivered as promised in FY2018 and is ready to deliver again.

Goal 1. OWAQ will continue to improve effective communication of weather information to strengthen decision-making and forecasting abilities by:

- Applying theoretical knowledge about behavioral responses to predictions, warnings, and forecasts in specific domains.
- Improving the transition of social and behavioral research into operations.
- Embedding social sciences in the physical sciences.
- Improving dissemination of ideas and best practices to stakeholders.

Goals 2. OWAQ will continue to advance models and forecast tools to produce the best weather forecasts and warnings to build a Weather-Ready Nation with an overall focus on improving model physics, developing enhanced hazard mitigation strategies, accelerating the development of capabilities, and incorporating evaluation. In turn, this means:

- Expanding Next Generation Global Prediction System elements related to severe weather prediction, especially landfalling tropical storms and hurricanes.
- Supporting the next generation of mesoscale weather-observing platforms.
- Improving the Finite-Volume Cubed (FV3)-based ensemble prediction system.
- Improving storm-surge modeling.
- Accelerating the development of the Joint Effort for Data assimilation Integration infrastructure.
- Accelerating assimilation of new satellite and other observational data and optimization of current data assimilation.
- Accelerating, testing, and evaluating forecast impacts from new data assimilation capabilities in regional and global atmospheric, marine, land, hurricane, and hydrological models.
- Evaluating impacts from satellite observing system components and mitigation of forecast skill drop-outs.

FIGURE 23. Potomac River Overflowing Its Banks Near Harpers Ferry, West Virginia. Image credit: Janet Ward (February 2000) for NOAA's Photo Library.

To improve understanding of tropical cyclones, OWAQ will support improvements to the current hurricane prediction system and improvements in National Hurricane Center forecast techniques to improve seasonal hurricane forecasts. OWAQ also will support the continued availability and use of ocean observation platforms and systems for improvements to hurricane forecasting skill, specifically in regard to intensity and track.

To improve understanding of tornadoes, OWAQ will continue to support VORTEX-SE, as requested, so scientists can study the storms that produce tornadoes in the Southeast U.S. by examining historical data and applying state-of-the-art numerical weather prediction and data assimilation systems.

To improve understanding of air quality, OWAQ will improve air quality research and forecasting because the current NOAA operational forecast challenges for fine particulate matter (PM2.5) and ozone predictions include improving emissions from sources such as wildfire smoke and dust as well as chemical mechanisms.

Goal 3. To effectively and efficiently manage the advancement and transition of weather research into societal applications, OWAQ will focus on applied research, development, and, in particular, the demonstration and testing of that research in NOAA's quasi-operational forecasting environment. To improve the technology transfer effectiveness and efficiency, OWAQ will support development, testing, and evaluation of mature weather research that has the potential to improve NOAA's NWS operational capabilities, particularly in the areas of advancing numerical weather prediction capabilities that seamlessly integrate in the NOAA Unified Forecast System, water prediction capabilities, and forecasts of extreme precipitation and

FIGURE 24. A Supercell Moves East of Denver, Colorado. Image credit: Susan Cobb for NOAA's National Severe Storms Laboratory (June 2006).

flooding events. This also includes improving the efficiency, effectiveness, and accuracy of obtaining snowpack and soil moisture observations.

OWAQ will advance research at the subseasonal-to-seasonal time frame and will simultaneously advance predictive capability and understanding of precipitation on the S2S scale via improved data assimilation, especially coupled data assimilation including new observation types; Earth system model processes for precipitation and high-impact events; and ensemble techniques, composition, and post-processing, including multi-model ensembles.

Goal 4. To develop and support a diverse and inclusive work environment that promotes equal access to the opportunities OWAQ offers, OWAQ will continue to assemble a workforce that understands and responds to OWAQ's partners and stakeholders. Workforce diversity also will ensure that the interdisciplinary demands for weather research and development expertise are continuously met while building a work environment that encourages open communication, provides fair and equitable opportunities, and empowers employees with the resources and support they need to advance and support our mission of science, service, and stewardship.

In support of the overall diversity of the weather enterprise, OWAQ will continue to strengthen engagement with underrepresented groups, particularly with NOAA's Cooperative Science Centers, Historically-Black Colleges and Universities, Hispanic-Serving Institutions, and Tribal Colleges and Universities.

Conclusion

We cannot avoid weather, but we can learn more about what to expect and when to expect it. Count on OWAQ to learn from this year's accomplishments while continuing to make prioritized, sustained investments in weather and air quality research. With our partners, we will fulfill our vision of a Weather-Ready Nation informed by world-class weather research.

Visit https://owaq.noaa.gov for funding opportunities, student and teacher resources, and more.

Appendix A: Projects

ACTIVE PROJECTS IN FY2018 (alphabetical by title)

Accounting for Non-Gaussianity in the Background Error Distributions Associated with Cloud-Related Variables (Microwave Radiances and Hydrometeors) in Hybrid Data Assimilation for Convective-Scale Prediction | Lead PI(s) Karina Apodaca | Colorado State University | 10/01/2016 - 09/30/2019

Adding TC Genesis Verification Capabilities to the Model Evaluation Tools - TC Software | Lead PI(s) Daniel Halperin | Embry-Riddle | 09/01/2018 - 08/31/2020

Advancing Frequently-Updating Storm-Scale Ensemble Data Assimilation and Prediction Towards Operations | Lead PI(s) Curtis Alexander | OAR/ESRL/GSD | 11/01/2017 - 10/31/2020

Advancing Social and Behavioral Science Research and Application within the Weather Enterprise | National Academy of Sciences | 03/08/2016 - 03/07/2018

Airborne Phased Array Radar (APAR) Development and Risk Mitigation Project | Lead PI(s) Vanda Grubišić | National Center for Atmospheric Research | 10/1/2017 - 3/31/2019

Alliance for Integrative Approaches to Extreme Environmental Events | Lead PI(s) Kimberly Klockow | Cooperative Institute for Mesoscale Meteorological Studies | 05/01/2017 - 05/31/2018

Assessing the Impact of Assimilating Ground-Based Infrared Radiometer Data into Convective-Scale Numerical Weather Prediction Models | Lead PI(s) Timothy Wagner | University of Wisconsin-Cooperative Institute for Meteorological Satellite Studies | 10/01/2016 - 09/30/2019

Assessing the Impact of Stochastic Cloud Microphysics in Convection-Resolving Models Using GOES-R Satellite Observations | Lead PI(s) Jason Otkin, Gregory Thompson, and Fanyou Kong | University of Wisconsin-Cooperative Institute for Meteorological Satellite Studies; National Center for Atmospheric Research; and University of Oklahoma | 08/01/2017 - 07/31/2019

Assessment of Hydrologic Forecasts Generated Using Multi-Model and Multi-Precipitation Product Forcing | Lead PI(s) Witold Krajewski | University of Iowa | 07/01/2017 - 06/30/2019

Assimilation of Lake and Reservoir Levels into the WRF-Hydro National Water Model to Improve Operational Hydrologic Predictions | Lead PI(s) David Gochis, Allen Burton, and Lynn Johnson | University Corporation for Atmospheric Research; Great Lakes Environmental Research Laboratory (GLERL); Colorado State University-Cooperative Institute for Research in the Atmosphere | 10/01/2016 - 09/30/2019

Assimilation of Remote Sensing Observations into Convective-scale NWP to Improve 0-6 h Probabilistic Forecasts of High Impact Weather | Lead PI(s) Nusrat Yussouf | Cooperative Institute for Mesoscale Meteorological Studies | 10/01/2016 - 09/30/2019

Augmentation of VORTEX-SE Intensive Observations Period Measurements with Infrasound Observations to Detect and Track Tornadoes | Lead PI(s) Carrick Talmadge | University of Mississippi | 10/01/2016 - 12/31/2017

Automated High-Resolution Ensemble-Based Hazard Prediction Tool | Lead PI(s) Curtis Alexander | OAR/ESRL/GSD | 05/01/2015 - 04/30/2018

Building a Distributed Earth System Model Development Community | Lead PI(s) Cecelia DeLuca | CIRES NOAA ESRL | 10/1/2017 - 9/30/2018

Comparison of Model versus Observationally-Driven Water Vapor Profiles for Forecasting Heavy Precipitation Events | Lead PI(s) John Forsythe | Colorado State University-Cooperative Institute for Research in the Atmosphere | 07/01/2017 - 06/30/2019

Convection-Allowing Ensemble Prediction for Heavy Precipitation in Support of the Hydrometeorology Testbed (HMT): New QPF Products, Data Assimilation Techniques and Prediction Model | Lead PI(s) Ming Xue | University of Oklahoma | 07/01/2017 - 06/30/2019

Convection-Permitting Ensemble Forecast System for Prediction of Extreme Weather | Lead PI(s) Glen Romine, Michael Coniglio | University Corporation for Atmospheric Research; Cooperative Institute for Mesoscale Meteorological Studies | 09/01/2015 - 08/31/2018

Critical Steps toward a National Global Ocean Modeling Capability in Support of ESPC | Lead PI(s) Robert Hallberg | Geophysical Fluid Dynamics Laboratory | 10/1/2017 - 9/30/2018 | See also page 17

Demonstration of a Rapid Update Convection-Permitting Ensemble Forecast System to Improve Flash Flood and Winter Weather Prediction | Lead PI(s) Glen Romine | National Center for Atmospheric Research | 07/01/2017 - 06/30/2019

Demonstration of a Rapid Update Convection-Permitting Ensemble Forecast System to Improve Hazardous Weather Prediction | Lead PI(s) Glen Romine | National Center for Atmospheric Research | 07/01/2017 - 06/30/2019

Demonstration of an Airborne Hyperspectral and Thermal Imaging System to Assess Convective Lifted Index | Lead PI(s) Steve Brooks | The University of Tennessee | 10/01/2016 - 09/30/2018 | See also page 10

Developing a Unified Online Air Quality Forecasting System Based on CMAQ and NGGPS | Lead PI(s) Georg Grell | NOAA/OAR/ESRL | 06/01/2016 - 05/31/2019

Developing an Objective Evaluation Scorecard for Storm Scale Prediction | Lead PI(s) Tara Jensen | National Center for Atmospheric Research | 07/01/2017 - 06/30/2019

Developing and Evaluating GSI-based EnKF-Variational Hybrid Data Assimilation for NCEP NAMRR to Improve Convection-Allowing Hazardous Weather Forecast | Lead PI(s) Xuguang Wang | University of Oklahoma | 09/01/2015 - 08/31/2019

Development and Evaluation of New Statistical Calibration Methods for Multi-Model Ensemble Weeks 3-4 Probabilistic Forecasts | Lead PI(s) Nicolas Vigaud | Columbia University | 09/01/2018 - 08/31/2020

Development and Implementation of Probabilistic Hail Forecast Products Using Multi-Moment Microphysics and Machine Learning Algorithms | Lead PI(s) Nathan Snook | The University of Oklahoma | 10/01/2016 - 09/30/2019

Development and Optimization of Radar-Assimilating Ensemble-Based Data Assimilation for Storm-Scale Ensemble Prediction in Support of HWT Spring Experiments | Lead PI(s) Ming Xue | University of Oklahoma - Center for Analysis and Prediction of Storms | 07/01/2017 - 06/30/2019

Development of NWS Convective Scale Ensemble Forecasting Capability through Improving GSI-Based Hybrid Ensemble-Variational Data Assimilation and Evaluating the Multi-Dynamic Core Approach | Lead PI(s) Xuguang Wang | The University of Oklahoma | 10/01/2016 - 09/30/2019

Direct Detection of Tornadoes Using Infrasound Remote Sensing: Assessment of Capabilities through Comparison with Dual Polarization Radar and Other Direct Detection Measurements | Lead PI(s) Hank Rinehart and Kevin Knupp | General Atomics and University of Alabama-Huntsville | 10/01/2016 - 09/30/2018

Enabling Effective Use of Deterministic-to-Probabilistic Precipitation Forecasts for Heavy and Extreme Events | Lead PI(s) Tara Jensen | National Center for Atmospheric Research | 07/01/2017 - 06/30/2019 | See also page 17

Ensemble-Based Pre-genesis Watches and Warnings for Atlantic and North Pacific Tropical Cyclones: Lead PI(s) Russell Elsberry | University of Colorado-Colorado Springs | 07/01/2017 - 06/30/2019

Estimation of Tropical Cyclone Intensity Using Satellite Passive Microwave Observations | Lead PI(s) Haiyan Jiang | Florida International University | 07/01/2017 - 06/30/2019

Evaluating Stochastic Physics Approaches within Select Convection Allowing Model (CAM) members included in the Community Leveraged Unified Ensemble (CLUE) during the Hazardous Weather Testbed (HWT) Spring Experiment | Lead PI(s) Jamie Wolff and Isidora Jankov | National Center for Atmospheric Research; Colorado State University-Cooperative Institute for Research in the Atmosphere | 07/01/2017 - 06/30/2019

Evaluation and Diagnosis of National Water Model Simulations Over CONUS Ising a Novel Snow Reanalysis Dataset | Lead PI(s) Konstantinos Andreadis | University of California Los Angeles | 09/01/2018 - 08/31/2020 | See also page 12

Evaluation and Improvements of Tornado Detection Using Infrasound Remote Sensing: Comparative Analysis of Infrasound, Radar, Profiler, and Meteorological Data Sets, and Potential Impacts on NOAA/NWS Operations | Lead PI(s) Hank Rinehart and Kevin Knupp | General Atomics and University of Alabama-Huntsville | 10/01/2017 - 09/30/2019

Evolutionary Programming for Probabilistic Tropical Cyclone Intensity Forecasts | Lead PI(s) Paul Roebber | University of Wisconsin-Milwaukee | 07/01/2017 - 06/30/2019

An Examination of the State of Knowledge on Risk Perceptions and Understanding Response to Uncertainty Information | Lead PI(s) Terri Adams | Howard University | 08/01/2017 - 07/31/2018

Extending the Rapidly-Updating Real-Time Mesoscale Analysis (RTMA) to Three Dimensions for Whole-Atmosphere Situational Awareness and Analysis of Record | Lead PI(s) Curtis
Alexander | NOAA/OAR/ESRL/GSD | 11/01/2017 - 10/31/2020

FACETs: Advancing Physical and Social Science Concepts toward Operational Implementation of Probabilistic Hazard Information | Lead PI(s) Alan Gerard | OAR/NSSL | 11/01/2017 - 10/31/2020 | See also page 17

FACETs: Developing Operationally-Ready Hazard Services-Probabilistic Hazard Information (PHI) for Convective Hazards | Lead PI(s) Tracy Hansen | NOAA/OAR/ESRL/GSD | 11/01/2017 - 10/31/2020

Forecast Guidance for Aviation Tactical Operations and Strategic Planning over Alaska | Lead PI(s) Judy Ghirardelli | NOAA/NWS/STI/DFSB | 11/01/2017 - 10/31/2020

Forecast System Development Activities toward a Convective-Scale HRRR Ensemble | Lead PI(s) Glen Romine | National Center for Atmospheric Research | 08/01/2017 - 07/31/2019

Guidance on Observational Undersampling over the Tropical Cyclone Lifecycle | Lead PI(s) David Nolan and Eric Uhlhorn | University of Maryland and NOAA/OAR/AOML | 09/01/2015 - 08/31/2018

Guidelines for Expressing Uncertainty in Impact Decision Support Service Products Supplement to NSF Award Improving Public Response to Weather Warnings | Lead PI(s) Susan Joslyn | University of Washington | 09/01/2016 - 09/01/2019 | See also page 17

Identification of the Fluid Mechanisms Associated with Tornadic Storm Infrasound | Lead PI(s) Brian Elbing | Oklahoma State University | 09/01/2018 - 08/30/2020

The Impact of Ocean Resolution in the Unified Forecast System (UFS) on the Subseasonal Forecast of Extreme Hydrological Events | Lead PI(s) Cristiana Stan | George Mason University | 09/01/2018 - 08/31/2020 |
See also page 17

Implementation of a Three-Dimensional Hydrometeor Classification Algorithm within the Multi-Radar/Multi-Sensor System | Lead PI(s) | Heather Reeves | University of Oklahoma - Cooperative Institute for Mesoscale Meteorological Studies | 08/01/2017 - 07/31/2019

Implementation of Advanced Multi-Sensor Analysis and Data Fusion Algorithms for Real-Time High-Resolution Quantitative Precipitation Estimation | Lead PI(s) Dong-Jun Seo and Lin Tang | The University of Texas at Arlington and The University of Oklahoma | 10/01/2016 - 09/30/2019

Implementation of Multi-Radar Multi-Sensor Dual-Polarization Radar Synthetic QPE | Lead PI(s) Stephen Cocks | University of Oklahoma - Cooperative Institute for Mesoscale Meteorological Studies | 08/01/2017 - 07/31/2019

Implementation of Nested Hyper-Resolution Modeling with Data Assimilation for the National Water Model | Lead PI(s) Dong-Jun Seo | University of Texas-Arlington | 08/01/2017 - 07/31/2019

Implementation of Streamflow Data Assimilator for the National Water Model to Improve Water Prediction and Analysis | Lead PI(s) Seongjin Noh and James McCreight | University of Texas-Arlington and National Center for Atmospheric Research | 08/01/2017 - 07/31/2019

Implementing Snow Data Assimilation Capabilities for the National Water Model and Experimental Assimilation of JPSS Observations of Snow Water Equivalent | Lead PI(s) Yu Zhang and Cezar Kongoli | University of Texas Arlington and University of Maryland | 09/01/2018 - 08/31/2020

Improved Eyewall Replacement Cycle Forecasting Using a Modified Microwave-Based Algorithm (ARCHER) | Lead PI(s) Anthony Wimmers | University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies | 09/01/2015 - 08/31/2018 | See also page 9

Improvement and Implementation of the Probability-based Microwave Ring Rapid Intensification Index for NHC/JTWC Forecast Basins | Lead PI(s) Haiyan Jiang and Kate Musgrave | Florida International University and Colorado State University-Cooperative Institute for Research in the Atmosphere | 09/01/2015 - 08/31/2018

Improvement of WRF-Hydro National Water Model Architecture and Calibration Methods for Semi-Arid Environments with Complex Terrain | Lead PI(s) Christopher Castro | University of Arizona | 08/01/2017 - 07/31/2019

Improvement to the Tropical Cyclone Genesis Index (TCGI) | Lead PI(s) Jason Dunion, Andrea Schumacher, John Kaplan, and Josh Cossuth | University of Maryland; Colorado State University-Cooperative Institute for Research in the Atmosphere; NOAA/OAR/AOML; and Naval Research Laboratory | 09/01/2015 - 08/31/2018

Improvements and Extensions to an Existing Probabilistic Genesis Forecast Tool Using an Ensemble of Global Models | Lead PI(s) Robert Hart | Florida State University | 07/01/2017 - 06/30/2019

Improvements in Operational Statistical Tropical Cyclone Forecast Models | Lead PI(s) Galina Chirokova | Colorado State University-Cooperative Institute for Research in the Atmosphere | 09/01/2015 - 08/31/2018

Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models using Wind Structure and Eye Predictors | Lead PI(s) Galina Chirokova and John Kaplan | Colorado State University-Cooperative Institute for Research in the Atmosphere and NOAA/OAR/AOML | 08/01/2017 - 07/31/2019 | See also page 8

Improving Hydrologic Observing Capabilities with Stream Radars | Lead PI(s) Daniel Wasielewski | Cooperative Institute for Mesoscale Meteorological Studies | 10/01/2016 - 09/30/2019 | See also page 12

Improving Initial Conditions and Their Perturbations through Ensemble-Based Data Assimilation for Optimized Storm-Scale Ensemble Prediction in Support of HWT Severe Weather Forecasting | Lead PI(s) Ming Xue | University of Oklahoma | 09/01/2015 - 08/31/2018

Improving Lake-Effect Snow and Ice Forecasting for the Great Lakes Region | Lead PI(s) Philip Chu | Great Lakes Environmental Research Laboratory (GLERL) | 07/01/2017 - 06/30/2019

Improving National Water Model Snowmelt Runoff Prediction | Lead PI(s) Guo-Yue Niu and Michael Barlage | University of Arizona and National Center for Atmospheric Research | 09/01/2018 - 08/31/2020

Improving NWS Convection Allowing Hazardous Weather Ensemble Forecasts through Optimizing Multi-Scale Initial Condition (IC) Perturbations | Lead PI(s) Xuguang Wang | University of Oklahoma/Cooperative Institute for Mesoscale Meteorological Studies | 07/01/2017 - 06/30/2019

Improving Probabilistic Forecasts of Extreme Rainfall through Intelligent Processing of High-Resolution Ensemble Predictions | Lead PI(s) Russ Schumacher | Colorado State University | 10/01/2016 - 09/30/2019 | See also page 11

Improving the Design and Utility to Severe Weather Forecasters of Convection Permitting Ensembles through Application of a Probabilistic Object-Based Post-Processing and Verification Technique | Lead PI(s) Aaron Johnson | University of Oklahoma | 07/01/2017 - 06/30/2019

Improving the Prediction of Subseasonal Global Rainfall Variability through the Use of a Scale-Adaptive Stochastic Physics Suite | Lead PI(s) Jian-Wen Bao | NOAA/OAR/ESRL/PSD | 11/01/2017 - 08/31/2020

Improving the Use of Dropsondes in NOAA Operations (HWRF) | Lead PI(s) Jason Sippel | AOML | 11/01/2017 - 09/30/2019 | See also page 8

Information Extraction and Verification of Convection-Allowing Models for Severe Hail Forecasting | Lead PI(s) Israel Jirak | National Weather Service-Storm Prediction Center | 09/01/2015 - 08/31/2018 | See also page 10

Infrasound Detection of Tornadoes | Lead PI(s) Roger Waxler | University of Mississippi | 09/01/2017 - 12/31/2019

Infrasound Detection of Tornadoes (FY18): Lead PI(s) Roger Waxler | University of Mississippi | 09/01/2018 - 08/30/2020

INSITE: Integrated Support for Impacted Air Traffic Environments | Lead PI(s) Joshua Scheck | NOAA/NWS/NCEP | 11/01/2017 - 12/31/2020

Integration and Evaluation of ProbSevere within the Probabilistic Hazard Information (PHI) Tool in the Hazardous Weather Testbed | Lead PI(s) Kristin Calhoun, Wayne Feltz, Lans Rothfusz, and Michael Pavolonis | University of Oklahoma; University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies; National Severe Storms Laboratory; and National Environmental Satellite, Data, and Information Service | 09/01/2015 - 08/31/2018 | See also page 11

Integration of Multi-Radar Multi-Sensor Azimuthal Shear into a CONUS Conditional Probability of Tornado Intensity Product in the Hazardous Weather Testbed | Lead PI(s) Brandon Smith and Alan Gerard | University of Oklahoma - Cooperative Institute of Mesoscale Meteorological Studies and National Severe Storms Laboratory | 07/01/2017 - 06/30/2019

Multi-Radar/Multi-Sensor (MRMS) HMT-Hydro Experiment | Lead PI(s) Jonathan Gourley | NOAA/OAR/NSSL | 09/01/2015 - 08/31/2018 | See also page 12

Multi-Sensor Merged Quantitative Precipitation Estimations for Improved Precipitation Coverage and Accuracy | Lead PI(s) Steven Martinaitis | University of Oklahoma - Cooperative Institute for Mesoscale Meteorological Studies | 08/01/2017 - 07/31/2019

A Novel Ensemble Design for PM2.5 Probabilistic Predictions and Quantification of Their Uncertainty | Lead PI(s) Luca Monache | National Center for Atmospheric Research | 06/01/2016 - 05/31/2019

Operationalizing an Evaporative Demand Drought Index (EDDI) Service for Drought Monitoring and Early Warning Across CONUS | Lead PI(s) Robert Webb, Roger Pulwarty, and Michael Hobbins | NOAA/ESRL/PSD; NOAA/ESRL/PSD and National Integrated Drought Information Systems and University of Colorado and Cooperative Institute for Research in Environmental Sciences | 07/01/2016 - 06/30/2019

Optimizing Geostationary Lightning Mapper Use in AWIPS | Lead PI(s) Scott Rudlosky | NESDIS/STAR | 09/01/2017 - 08/31/2020

Post-Processing of CMAQ Air Quality Predictions: Research to Operations | Lead PI(s) Irina Djalalova | NOAA/OAR/ESRL/PSD and CIRES/University of Colorado | 06/01/2016 - 05/31/2019 | See also page 14

Prediction and Measurement of Infrasound Propagation in the Turbulent Atmosphere | Lead PI(s) Steven Miller | University of Florida | 09/01/2018 - 08/30/2020

Probabilistic Precipitation Rate Estimates from Ground-Radar for Hydrology | Lead PI(s) Pierre-Emmanuel Kirstetter | University of Oklahoma | 08/01/2017 - 07/31/2019

Probabilistic Prediction of Tropical Cyclone Rapid Intensification Using Satellite Passive Microwave Imagery | Lead PI(s) Chris Rozoff | University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies | 09/01/2015 - 08/31/2018 | See also page 9

Probabilistic Warn-on-Forecast System for Heavy Rainfall and Flash Flooding | Lead PI(s) Steven Martinaitis and Jonathan Gourley | University of Oklahoma - Cooperative Institute for Mesoscale Meteorological Studies and NOAA/OAR/NSSL | 10/01/2017 - 09/30/2019

Probability of What? Understanding and Conveying Uncertainty through Probabilistic Hazard Services | Lead PI(s) Alan Gerard | OAR/NSSL | 05/01/2015 - 04/30/2018

Quantifying Observational Requirements for WRF-Hydro Forcing in the West Using Russian River HMT Experience and Data to Inform National Water Center Tools | Lead PI(s) Fred Ralph | University of California San Diego - CIMEC | 07/01/2017 - 06/30/2019

Quantifying Stochastic Forcing at Convective Scales | Lead PI(s) David Randall | Colorado State University | 10/01/2016 - 09/30/2019

Top-Down Estimation of Wildfire Smoke Emission Based on HYSPLIT Model and NOAA NESDIS GOES Aerosol/Smoke Products to Improve Smoke Forecasts in the US | Lead PI(s) Tianfeng Chai | University of Maryland | 06/01/2016 - 05/31/2019 | See also page 14

Towards the Improvement of Chemical Lateral Boundary Conditions for the NAQFC | Lead PI(s) Zhining Tao, Huisheng Bian, and Daniel Tong | University of Space Research Association/NASA Goddard University of Maryland University of Maryland | 06/01/2016 - 05/31/2019

Transition of Machine-Learning Based Rapid Intensification Forecasts to Operations | Lead PI(s) Andrew Mercer | Mississippi State University-Northern Gulf Institute | 07/01/2017 - 06/30/2019

Transition of the Coastal and Estuarine Storm Tide Model to an Operational Model for Forecasting Storm Surges | Lead PI(s) Keqi Zhang | Florida International University | 09/01/2015 - 02/28/2019

Upgrades and Improvements to MRMS | Lead PI(s) Kenneth Howard and Jennifer Guillot | NOAA/OAR/NSSL and NOAA/NWS | 08/01/2016 - 07/31/2019

Use of MRMS-Derived Hydrometeor Classification for Determining Initial Hydrometeor Phase in the National Water Model | Lead PI(s) Heather Reeves, Mimi Hughes, and David Gochis | University of Oklahoma; Cooperative Institute for Research in Environmental Sciences and National Center for Atmospheric Research | 09/01/2018 - 08/31/2020 | See also page 13

Use of the Stochastic-dynamic Approach in a Single Dynamic-Core Storm-Scale Ensemble for Improved Spread and Reliability of QPF and Surface Variables | Lead PI(s) Isidora Jankov, Judith Berner, and Joseph Olson | Colorado State University-Cooperative Institute for Research in the Atmosphere; National Center for Atmospheric Research; and Cooperative Institute for Research in Environmental Sciences | 08/01/2017 - 07/31/2019

Using HYSPLIT Ensemble Dispersion Modeling for Forecasting Applications | Lead PI(s) Barbara Stunder | OAR/ARL | 09/01/2017 - 08/31/2020 | See also page 14

Validation and Improvement of Microphysical Parameterizations for Better Orographic Precipitation Forecasts | Lead PI(s) David Kingsmill | University of Colorado-Cooperative Institute for Research in Environmental Sciences | 09/01/2015 - 08/31/2018 | See also page 12

VSAFE: Verification Services for Aviation Forecast Evaluation | Lead PI(s) Joshua Scheck | NOAA/NWS/NCEP | 01/01/2018 - 12/31/2020

NOTE: For the latest list, visit https://OWAQ.noaa.gov.

Appendix B: Outreach

PUBLICATIONS

Bluestein, H. B., G. S. Romine, R. Rotunno, D. Reif, and C. Weiss, 2018: On the anomalous turning of the surface wind with time in the plains of the United States. Mon. Wea. Rev., 146, 467-484.

Clark, A.J., I.L. Jirak, S.R. Dembek, G.J. Creager, F. Kong, K.W. Thomas, K.H. Knopfmeier, B.T. Gallo, C.J. Melick, M. Xue, K.A. Brewster, Y. Jung, A. Kennedy, X. Dong, J. Markel, M. Gilmore, G.S. Romine, K.R. Fossell, R.A. Sobash, J.R. Carley, B.S. Ferrier, M. Pyle, C.R. Alexander, S.J. Weiss, J.S. Kain, L.J. Wicker, G. Thompson, R.D. Adams-Selin, and D.A. Imy, 2018: The Community Leveraged Unified Ensemble (CLUE) in the 2016 NOAA/Hazardous Weather Testbed Spring Forecasting Experiment. *Bull. Amer. Meteor. Soc.,* 99, 1433–1448, https://doi.org/10.1175/BAMS-D-16-0309.1

Gitro, C.M., Jurewicz, M.L., Kusselson, S.J., Forsythe, J.M., Kidder, S.Q., Szoke, E.J., Bikos, D.L, Jones, A.S., Gravelle, C.M., Grassotti, C, 2016: Using the Multisensor Advected Layered Precipitable Water Product in the Operational Forecast Environment, Journal of Operational Meteorology . 6/15/2018, Vol. 6 Issue 6, p59-73. 15p.

Habibi, H., Dasgupta, I., Noh, S., Kim, S., Zink, M., Seo, D.-J., Bartos, M., Kerkez, B., 2018. High-resolution hydrologic forecasting for very large urban areas. Submitted to the Journal of Hydroinformatics.

Herman, G.R. and R.S. Schumacher, 2018: Money Doesn't Grow on Trees, but Forecasts Do: Forecasting Extreme Precipitation with Random Forests. *Mon. Wea. Rev.,* 146, 1571–1600, https://doi.org/10.1175/MWR-D-17-0250.1

Herman, G.R. and R.S. Schumacher, 2018: "Dendrology" in Numerical Weather Prediction: What Random Forests and Logistic Regression Tell Us about Forecasting Extreme Precipitation. *Mon. Wea. Rev.,* 146, 1785–1812, https://doi.org/10.1175/MWR-D-17-0307.1

Hobbins MT, McEvoy DJ, and Hain C (2017), Evapotranspiration, evaporative demand, and drought, Chapter 11, in: Drought and Water Crises: Integrating Science, Management, and Policy, edited by DA Wilhite and RS Pulwarty, CRC Press, doi:10.1201/9781315265551.

Karstens, C. D., J. Correia Jr., D. LaDue, J. Wolfe, T. C. Meyer, D. R. Harrison, J. L. Cintineo, K. M. Calhoun, T. M. Smith, A. E. Gerard, and L. P. Rothsfusz, 2017: A Conceptual Model for Generating a Continuous Flow of Information for Severe Convective Events. Accepted with Minor Revisions. *Wea. Forecasting*, Feb. 2018.

Karstens, C.D., J. Correia, D.S. LaDue, J. Wolfe, T.C. Meyer, D.R. Harrison, J.L. Cintineo, K.M. Calhoun, T.M. Smith, A.E. Gerard, and L.P. Rothfusz, 2018: Development of a Human–Machine Mix for Forecasting Severe Convective Events. *Wea. Forecasting,* 33, 715–737, https://doi.org/10.1175/WAF-D-17-0188.1

Kim, B., D.-J. Seo, S. J. Noh, O. P. Prat, and B. R. Nelson, 2018. Improving multisensory estimation of heavy-to-extreme precipitation via conditional bias-penalized optimal estimation. Journal of Hydrology. 556: 1096-1109.

Knaff, J. A., and R. T. DeMaria, 2017: Forecasting tropical cyclone eye formation and dissipation in infrared imagery. *Wea. Forecasting*, 32(6), 2103-2116, doi: 10.1175/WAF-D-17-0037.1.

Kong, R., M. Xue, and C. Liu, 2018: Development of a hybrid en3DVar data assimilation system and comparisons with 3DVar and EnKF for radar data assimilation with observing system simulation experiments. Mon. Wea. Rev., 146, 175–198. https://doi.org/10.1175/MWR-D-17-0164.1

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Mazzoleni, M., Noh, S.J., Lee, H., Liu, Y., Seo, D.-J., Alfonso, L., Solomatine, D.P., 2018. Real-time assimilation of streamflow observations into a hydrologic routing model: Effects of different model structures and updating methods. Hydrological Sciences Journal, Vol. 13, Issue 3, https://doi.org/10.1080/02626667.2018.1430898

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Seo, B., F. Quintero, and W.F. Krajewski, 2018: High-Resolution QPF Uncertainty and Its Implications for Flood Prediction: A Case Study for the Eastern Iowa Flood of 2016. *J. Hydrometeor.,* 19, 1289–1304, https://doi.org/10.1175/JHM-D-18-0046.1

Seo, D.-J., M. Mohammad Saifuddin, and H. Lee, 2018. Conditional bias-penalized Kalman filter for improved estimation and prediction of extremes. Stochastic Environmental Research and Risk Assessment. 32(1): 183-201.

PRESENTATIONS

Apodaca K., Fletcher S. J., Weygandt S., and Lin H.: Implementing Non-Gaussian Background Error Statistics for Humidity and Hydrometeor Control Variables in the Hybrid GSI System for Improved Convective-Scale Assimilation and Prediction. Data Assimilation: Advances in Methodologies IV, 22nd Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface. 97th Annual Meeting of the American Meteorological, Austin, TX.

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Brooks, S., B. B. Baker, T. R. Lee, M. Buban, E. J. Dumas Jr., P. Krishnan, K. N. Ellis, and D. Burow, 2018: Airborne Thermal and Hyperspectral Imaging to Estimate Sensible and Latent Heat Fluxes during the Land Atmosphere Feedback Experiment (LAFE), AMS 23rd Symposium on Boundary Layers and Turbulence, 11-15 June 2018, Oklahoma City, OK.

Calhoun, K. M., C. D. Karstens, J. L. Cintineo, J. Sieglaff, G. J. Stumpf, J. J. James, and C. Ling, 2018: Integration of Automated Severe Weather Probabilistic Guidance within NWS Warnings in the Hazardous Weather Testbed. 8th Conf. on Transition of Research to Operations. American Meteorological Society. 7-12 Jan 2018. Austin, TX.

Chirokova G., J. Kaplan, and J. Knaff, 2018: Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models Using Wind Structure and Eye Predictors. 2018 Tropical Cyclone Operations and Research Forum (TCORF)/71th Interdepartmental Hurricane Conference (IHC), 2018, Miami, FL.

Cintineo, J. L, M. J. Pavolonis, J. Sieglaff, C. D. Karstens, and K.M. Calhoun, 2018: Automated Severe Thunderstorm Guidance from the NOAA/CIMSS ProbSevere Model within the Hazardous Weather Testbed. 8th Conf. on Transition of Research to Operations. American Meteorological Society. 7-12 Jan 2018. Austin, TX.

Cocks, S.B., L. Tang, Y. Wang, J. Zhang, A. Ryzhkov, P. Zhang, K. Howard, 2018: Operational Strengths and Challenges for the New MRMS Dual Pol QPE on a Real-Time System, AMS Annual Meeting, Austin, TX.

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Fletcher, S. J. and K. Apodaca, 2018: Implementing and Testing of a Lognormal-Based Humidity Control Variable for the NCEP GSI Hybrid EnVAR Assimilation Scheme. Data Assimilation: Advances in Methodologies IV, 22nd Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface. 97th Annual Meeting of the American Meteorological, Austin, TX.

Grimes, A., A. Mercer, and K. Wood, 2018: Evaluation of Machine-Learning Based Rapid Intensification Forecast Performance During the 2017 Atlantic Hurricane Season. AMS 33rd Conference on Hurricanes and Tropical Meteorology, Ponte Vedra, FL.

Goudeau, B., K. R. Knupp, W. G. Frazier, R. Waxler, C. Talmadge, and C. Hetzer, 2018: An Analysis of Tornado-Emitted Infrasound during the VORTEX-SE Field Campaign. 19th Symposium on Meteorological Observation and Instrumentation, Austin, TX.

Huang, J., J. McQueen, P. Shafran, H.-C. Huang, J. Wilczak, D. Allured, I. Djalalova, S. Upadhayay, and I. Stajner, 2017: Improvement of NOAA NAQFC Surface Ozone Predictions with a Bias Correction Approach, Community Modeling and Analysis System (CMAS) Conference, Chapel Hill, NC.

Jung, Y., M. Xue, G. Zhao, J. Luo, T. Supinie, C. Liu, R. Kong, F. Kong, and K. Thomas, 2018: Development of GSI-based EnKF and hybrid EnVar data assimilation capabilities for continental-scale 3-km convection-permitting ensemble forecasting and testing via NOAA hazardous weather testbed spring forecasting experiments, 29th Conf. Wea. Anal. Forecasting/25th Conf. Num. Wea. Pred., Denver, CO.

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Jiang, H., 2018: Tropical Cyclone Passive Microwave Intensity Estimation (PMW-IE) Model. AMS 33rd Conference on Hurricanes and Tropical Meteorology Session 15C, Ponte Vedra, FL.

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Lee, H., D.-J. Seo, Y. Zhang, S. Kim, and S. Noh, 2018: Improving Hydrologic Forecasting Using Ensemble Conditional Bias-Penalized Kalman Filter. AMS Annual Meeting. Austin, TX.

Martinaitis, S. M., C. Langston, A. Osborne, J. Zhang, K. Howard, and Y. Qi, 2018: Advancing precipitation estimation in data-sparse regions – The MRMS Multi-Sensor QPE product. 32nd Conf. on Hydrology, Austin, TX.

Mercer, A. K. Wood, and A. Grimes, 2018: Transition of Machine-Learning Based Rapid Intensification Forecasts to Operations. Trop. Cyclone Res. And Operations Forum, Miami, FL.

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Pei, Y., H. Jiang, K. Musgrave, J. Zawislak, and G. Chirokova, 2018: Improvement and Implementation of the Probability-based Microwave Ring Rapid Intensification Index (PMWRing RII) for NHC/JTWC Forecast – Year 3 Update, 72nd Interdepartmental Hurricane Conference/ Tropical Cyclone Research Forum, Miami, FL.

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Schumacher A., G. Chirokova, J. Knaff, and M. DeMaria, 2018: Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models. 98th AMS Annual Meeting / 22nd Conference on Satellite Meteorology and Oceanography, Austin Tx.

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Wang, X. and Y. Wang, 2018: R2O: Development of NWS Convective-Scale Data Assimilation and Ensemble Forecasting Capability to Improve Operational Hazardous Weather Forecasts. AMS annual meeting, Austin, TX.

Wong, M. et al., 2018: Diagnosis of model physics errors using a convection-permitting ensemble data assimilation system, 2nd Pan-GASS meeting, Victoria, Australia.

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NOTE: Partial list as provided in progress reports and listed in conference programs.

Endnotes

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7 NOAA. 2019. "Hurricanes." https://www.noaa.gov/education/resource-collections/weather-atmosphere-education-resources/hurricanes.

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9 Ibid.

10 For additional tropical cyclone research priorities and/or details, visit https://owaq.noaa.gov.

11 NOAA National Centers for Environmental Information. 2018. "Severe Weather Data." ncdc.noaa.gov/data-access/severe-weather.

12 NOAA National Weather Service. 2019. "NWS StormReady Program: Working Toward a Weather-Ready Nation." https://www.weather.gov/stormready/.

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14 For additional hazardous weather research priorities and/or details, visit https://owaq.noaa.gov.

15 NOAA National Weather Service. 2017. "Summary of Natural Hazard Statistics for 2016 in the United States." http://www.nws.noaa.gov/om/hazstats/sum16.pdf.

16 NOAA National Centers for Environmental Information. 2019. "Billion-Dollar Weather and Climate Disasters: Summary Stats." https://www.ncdc.noaa.gov/billions/summary-stats.

17 For additional flooding and drought research priorities and/or details, visit https://owaq.noaa.gov.

18 For additional air quality research priorities, visit https://owaq.noaa.gov.

19 For additional information about testbeds and proving grounds, visit https://www.testbeds.noaa.gov/.

20 For additional interdisciplinary research priorities and/or details, visit https://owaq.noaa.gov.

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