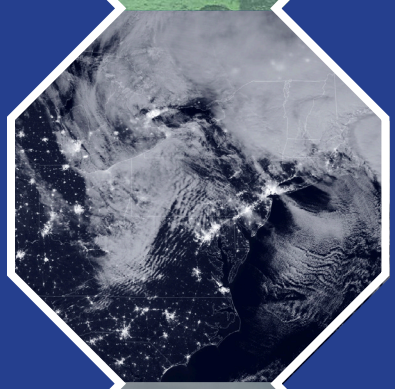

2019

NOAA Science Report

National Oceanic and Atmospheric Administration

U.S. Department of Commerce

NOAA Technical Memorandum NOAA Research Council-002

2019 NOAA Science Report

Gina Digiantonio, Emma Kelley, Eric Bayler, Neil Christerson, Sarah Davis, Kurt Dreflak, Jawed Hameedi, Michael Liddel, Gary Matlock, Laura Newcomb, Jamie Roberts, Peter Roohr

NOAA
Silver Spring, Maryland

February 2020

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NATIONAL OCEANIC AND
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UNITED STATES DEPARTMENT OF COMMERCE

Wilbur Ross
Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Foreword

As the Nation's premier ocean, weather, and atmospheric science agency, the National Oceanic and Atmospheric Administration (NOAA) continuously conducts world class research to improve the lives and livelihoods of American citizens. NOAA scientists work to explore, observe, and understand our world from the depths of the ocean to the surface of the sun, providing important information to the public, emergency managers, and decision-makers.

In 2019, NOAA and our partners applied machine learning to improve severe weather forecasting, developed new tools to track oil spills and improve responses, conducted research to understand the health implications of wildfires, used drones to map coastlines, developed new tools to forecast, detect, and track harmful algal blooms (HAB), and much more.

This year, NOAA also took steps forward to finalize and begin implementing agency strategies for artificial intelligence, unmanned systems, 'omics, and the cloud. These strategies will ensure robust, agency-wide coordination and strong institutional support for these four important science and technology focus areas, enabling transformational advances in the quality and efficiency of NOAA's science, products, and services.

The 2019 Science Report provides a snapshot of some of the many research accomplishments from NOAA and our academic and industry partners. NOAA's research and development enterprise contributed to the following three priorities:

1. *Reduce societal impacts from hazardous weather and other environmental phenomena.* For example, NOAA researchers used high-performance computing (HPC) systems to help meteorologists and other scientists put satellite imagery and data to work to improve the accuracy of forecasts, simulate dangerous weather patterns, and create better early warning systems for hurricanes, tsunamis, tornadoes, and other catastrophic weather events.

2. *Enable the sustainable use and stewardship of ocean and coastal resources.* For example, NOAA funded a regional pilot study to evaluate the economic impacts of marine debris on tourism-dependent communities. This study may inform the prioritization of areas where prevention and removal efforts are needed.

3. *Advance a robust and effective research, development, and transition enterprise.* For example, NOAA is creating a community modeling framework for the Unified Forecast System, the next-generation Earth system modeling capability. With this framework, NOAA will be able to transition research to operations for improved modeling and forecasting of high impact weather events. Additionally, we will be following up from the November 2019 White House Summit on Ocean Science and Technology Partnerships by implementing the Presidential Memorandum to map, explore, and characterize our EEZ.

NOAA's scientific achievements, which are recognized by numerous outside organizations, are made possible by our highly skilled and dedicated workforce. For this reason, the 2019 NOAA Science Report highlights NOAA's commitment to scientific integrity and diversity and inclusion.

This year's Science Report, representing a selection of NOAA's work on behalf of the American People, showcases NOAA's dedication to using cutting-edge research and high-tech instrumentation to provide the highest quality products and services, as well as NOAA's commitment to our mission of science, service, and stewardship.

RDML Tim Gallaudet, Ph.D., USN Ret.
Assistant Secretary of Commerce for Oceans and Atmosphere and
Deputy NOAA Administrator

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Acting Under Secretary Neil Jacobs (left), Deputy Secretary of Commerce Karen Dunn Kelley (center), and Ken Graham, Director of the NOAA National Hurricane Center (right) at the National Hurricane Center for Hurricane Season Kick-off. Photo credit: NOAA

Assistant Secretary Tim Gallaudet on the Maryland pilots tour. Photo credit: NOAA

NOAA group at International Association of Emergency Managers Conference. Photo credit: NOAA

Introduction

Enriching Life Through Science

Extending from the surface of the sun to the depths of the oceans, the mission of the National Oceanic and Atmospheric Administration (NOAA) depends on a strong research and development (R&D) foundation for observing and understanding the complex environmental systems that define our planet.

This understanding ultimately provides a range of users with the information and knowledge needed to protect lives, support livelihoods, improve economic efficiency, and enhance life. NOAA products and services provide daily weather forecasts that help protect human life and property, guide maritime commerce, and inform fisheries management and marine ecosystem conservation.

Why Does NOAA Invest in Research?

NOAA's investment in research is critical to continually improve the quality of NOAA's products and services for the Nation.

These products and services are developed through dynamic engagement between the agency and its users: stakeholders communicate their needs to NOAA, sparking new research initiatives or improvements to current services, while NOAA continues to improve research and services to meet the needs of the people who depend on them, as well as in response to legislation.

By integrating research conducted internally with the efforts of our partners, including cooperative institutes, universities, other government agencies, and the private sector, NOAA can transform concepts into the data, tools, and information upon which our stakeholders rely.

In short, NOAA balances a broad research portfolio to serve a wide spectrum of end users.

NOAA's Mission: Science, Service, and Stewardship

1. To understand and predict changes in climate, weather, oceans, and coasts;

2. To share that knowledge and information with others; and

3. To conserve and manage coastal and marine ecosystems and resources.

NOAA's Priority Objectives

NOAA is supporting the Department of Commerce's Strategic Plan through two priority objectives [NOAA, 2018]:

1. Minimize the impacts of extreme weather and water events by implementing the Weather Research and Forecasting Innovation Act, with the underlying goal to regain world leadership in weather modeling.

2. Accelerating the American Blue Economy, with specific focus on reducing the nation's seafood trade deficit through expanded marine aquaculture.

Introduction

What Kinds of Research Does NOAA Support?

NOAA's R&D addresses the needs of the user community while advancing fundamental scientific understanding. Our R&D portfolio must allow the flexibility to consider contributions to the scientific knowledge base separately from (albeit related to) enhancing applicability.

In the context of the classical treatment by Donald Stokes [Stokes, 1997], we strive to position our investment primarily in "Pasteur's Quadrant," (Figure 1) while including critical investments aimed primarily at either advancing fundamental understanding or enhancing applications.

NOAA strategically invests across the risk-reward spectrum, pursuing a range of projects, from low-risk projects that result in incremental gains to high-risk projects with high potential gains but less certainty of success. This balanced approach sets NOAA on the cutting edge of R&D while still ensuring that user needs and expectations are met.

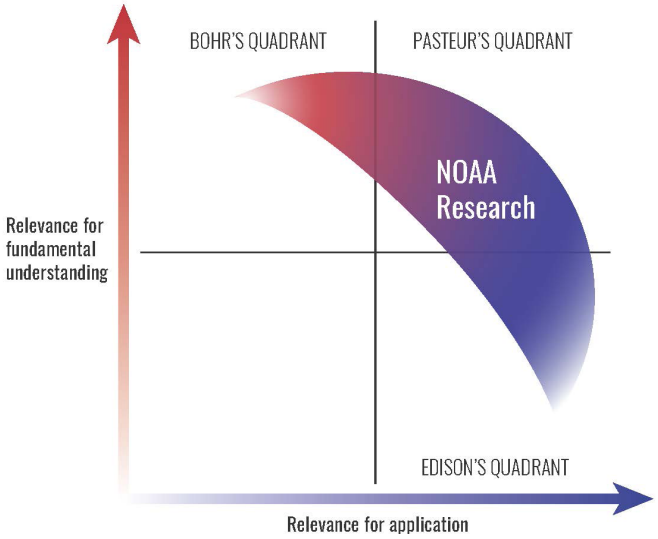


Figure 1. Donald Stokes proposed the above chart in his 1997 book Pasteur's Quadrant: Basic Science and Technological Innovation. *This chart portrays that, while some research largely focuses on fundamental understanding (Bohr's quadrant upper left) or application (Edison's quadrant, lower right), it is possible for research to be highly relevant for both fundamental understanding and real-life applications (Pasteur's quadrant, upper right). The majority of NOAA research strives for this dual relevance as reflected in Pasteur's quadrant.*

What Principles Guide NOAA Research?

NOAA strives to employ the following eight principles from NOAA Administrative Order (NAO) 216-115A [NOAA, 2016a] when formulating, directing, and evaluating all agency research: mission alignment, transition readiness (NAO 216-105B, [NOAA, 2016b]), research balance, optimized partnerships, sustained facilities and infrastructure, workforce excellence, scientific integrity, and accountability. These principles, grounded in communication within the agency and between our partners, work together to establish and maintain NOAA's high-quality research, development, services, and products.

NOAA maintains both intramural and extramural research investments, with some programs investing the majority of their R&D funding internally, at labs and science centers with Federal employees, and other programs investing the majority of their funding with external R&D partners at universities, industry, and other research institutions. In many cases, programs distribute their R&D investments across both intramural and extramural efforts.

NOAA partnerships, vital to the agency's R&D efforts, enable NOAA to leverage the expertise, equipment, and facilities of leading universities, Federal agencies, private companies, NGOs, and other science innovators. Key mechanisms for partnerships include Cooperative Institute and Cooperative Science Center agreements with universities; the network of university-based Sea Grant programs; extramural grant programs; contracts; and Cooperative Research and Development Agreements with the private sector.

Introduction

Scientific Integrity

NOAA ensures scientific integrity is a priority in order to promote a continuing culture of scientific excellence and strengthen the confidence in the quality, validity, and reliability of NOAA science. NOAA's Scientific Integrity Policy (NAO 202-735D [NOAA, 2011] and accompanying Procedural Handbook establish a Code of Scientific Conduct and a Code of Ethics for Science Supervision and Management to set the responsibilities of scientists, their managers, and those who use scientific results to set policy.

NOAA's Scientific Integrity Officer and Scientific Integrity Committee support the NOAA Research Council, NOAA Chief Scientist, and the NOAA Deputy Under Secretary for Operations in their respective responsibilities for oversight and implementation of NOAA's Scientific Integrity Policy.

The intent of the policy is to strengthen widespread confidence—from scientists, to decision-makers, to the general public—in the quality, validity, and reliability of NOAA science and to denote the agency's commitment to a culture of support for excellence of NOAA's principal science asset, its employees. NOAA's Scientific Integrity Policy is founded upon existing policies within the Department of Commerce and NOAA and updates and extends them substantially based on guidance from the Office of Science and Technology Policy and the Administration.

NOAA's Scientific Integrity Framework & Supporting Guidance includes procedures and policies for communication of research results with the media; communication of research products (including guidance on expressing individual opinion; and service in an official capacity to nonprofit organizations. These important Department of Commerce and NOAA policies make up NOAA's comprehensive scientific integrity framework.

Janet Duffy-Anderson,NOAA EcoFOCI Program Lead, and Knauss Fellow Chrissy Hayes rinse bongo nets for processing. Photo Credit: Lindsey Leigh Graham, NOAA

Introduction

All Six NOAA Line Offices Provide Unique Contributions to NOAA R&D

The **National Marine Fisheries Service (NMFS)**, also known as NOAA Fisheries, is responsible for the stewardship of the nation's ocean resources and their habitat. NOAA Fisheries provides vital services for the nation: productive and sustainable fisheries, safe sources of seafood, the recovery and conservation of protected resources, and healthy ecosystems—all backed by sound science and an ecosystem-based approach to management. Using the Magnuson-Stevens Act as the guide, NOAA Fisheries works in partnership with Regional Fishery Management Councils to assess and predict the status of fish stocks, set catch limits, ensure compliance with fisheries regulations, and reduce bycatch.

The **National Ocean Service (NOS)** is the nation's premier science agency for oceans and coasts. NOS delivers the applied science, modeling, tools and services needed to understand, predict, and respond to the challenges we face along America's 95,000 miles of shoreline and 3.5 million square miles of coastal, Great Lakes, and deep-ocean waters.

The **National Environmental Satellite, Data, and Information Service (NESDIS)** provides timely access to global environmental data from satellites and other sources to promote, protect, and enhance the Nation's economy, security, environment, and quality of life. NESDIS supports science through the Center for Satellite Applications and Research (STAR) and National Centers for Environmental Information (NCEI) (see NESDIS Laboratory and Program Science Review on page 70). Through these programs, NESDIS researches, formulates, develops, maintains, and sustains environmental measurements from satellites, as well as associated applications of satellite environmental observations, and maintains the quality of NOAA's operational satellite measurements, directly enabling and supporting NOAA's environmental analysis and prediction capabilities. NESDIS hosts and provides public access to one of Earth's most comprehensive archives for atmospheric, oceanic, and geophysical data, with research and development focusing on preserving, stewarding, and providing the best possible long-term environmental data records; thereby, maximizing the data's utility and enabling the Nation's environmental science efforts.

Introduction

The **Office of Oceanic and Atmospheric Research (OAR)**, also known as NOAA Research, provides the research foundation for understanding the complex earth systems that support our planet. OAR's role is to provide unbiased science to better manage the environment nationally and globally. The science and technology that OAR produces and transfers to partners (in NOAA's service lines and beyond) is instrumental to preventing the loss of human life, managing natural resources, and maintaining a strong economy. OAR has partnerships and platforms around the world and offices located across the country, including seven laboratories and six program offices that support research and provide information used from the international to the local level.

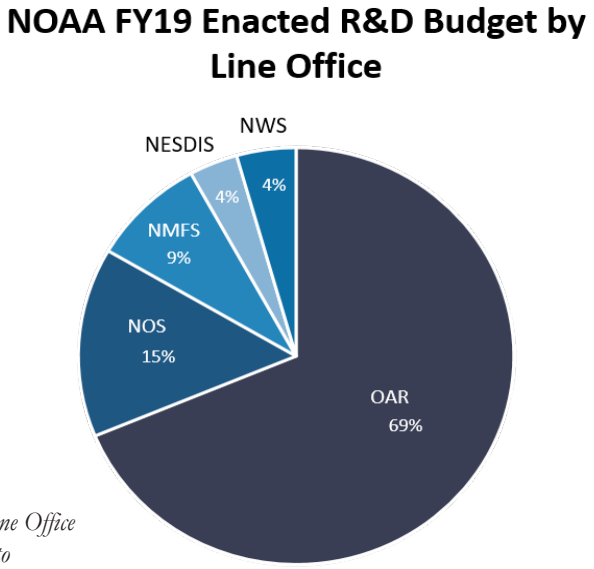
The **National Weather Service (NWS)** provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. NWS sustains and improves its observing system infrastructure with new technologies while leveraging more observations through innovative public and private partnerships; additionally, next generation weather and Earth system models are developed using a community-based approach, along with advances in high-performance computing. NWS also improves its tools, systems, and policies for virtualization, analytics, data management, and dissemination, ensuring full utilization of state-of-the art science, data sources, and technologies. Collaboration with partners across NOAA, other Federal agencies, and the Enterprise are critical to enable effective research to operations and operations to research activities for impact-based decision support services (IDSS).

The **Office of Marine and Aviation Operations (OMAO)** operates a wide variety of specialized aircraft and ships to complete NOAA's environmental and scientific missions. OMAO is also responsible for the administration and implementation of the Aviation Safety Program, Small Boat Program and NOAA Diving Program to ensure safe and efficient operations in NOAA-sponsored aviation, small boat and underwater activities.

Introduction

What is the Budget for NOAA Research?

NOAA dedicated $703 million, or approximately 13 percent of the agency's total budget, to R&D in fiscal year 2019 (FY19, with R&D defined as all research and development activities outside of R&D related facilities and equipment purchases). This continues a seven-year trend of increased R&D expenditures, highlighting NOAA's efforts to keep up with increased stakeholder demand for environmental intelligence and services in the face of a changing planet.

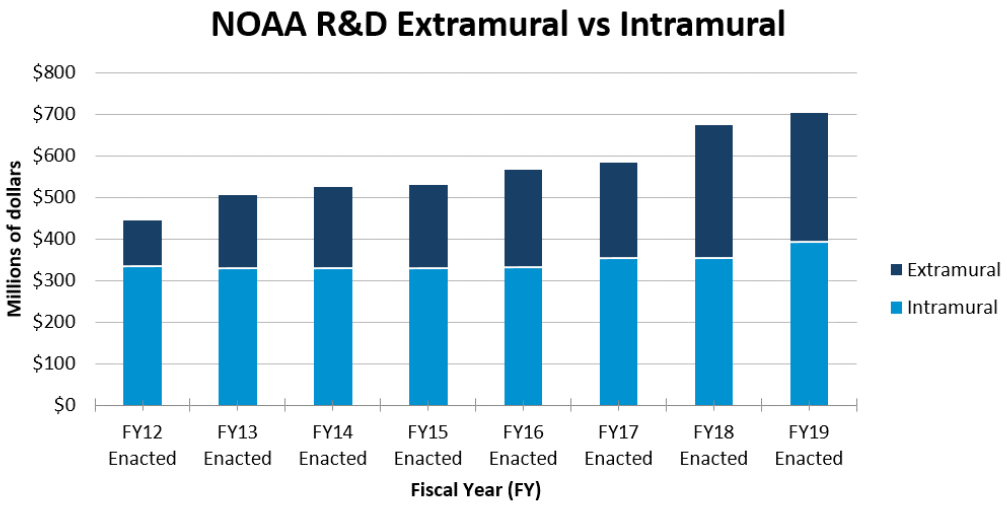


Note: OMAO tracks management and operation of aircraft and vessels in support of Line Office R&D as Equipment and therefore is not displayed here. NOAA satellite development to support operations and research is also not included. Percentages do not sum to 100 due to rounding.

Where Does it Go?

Approximately 55 percent of NOAA's FY19 R&D budget went to internal R&D efforts, including those at NOAA labs and science centers within the line offices. The remaining 45 percent was set aside for extramural research, enabling partnerships and collaborations with non-NOAA entities.

Note: All graphs exclude facilities and equipment from R&D budget calculations.



2019 Hurricane Supplemental R&D Activities

Research and development activities supported by Public-Law 116-20, *Additional Supplemental Appropriations for Disaster Relief, 2019*, are planned to accelerate the implementation of NOAA's existing improvement plans in relevant focus areas:

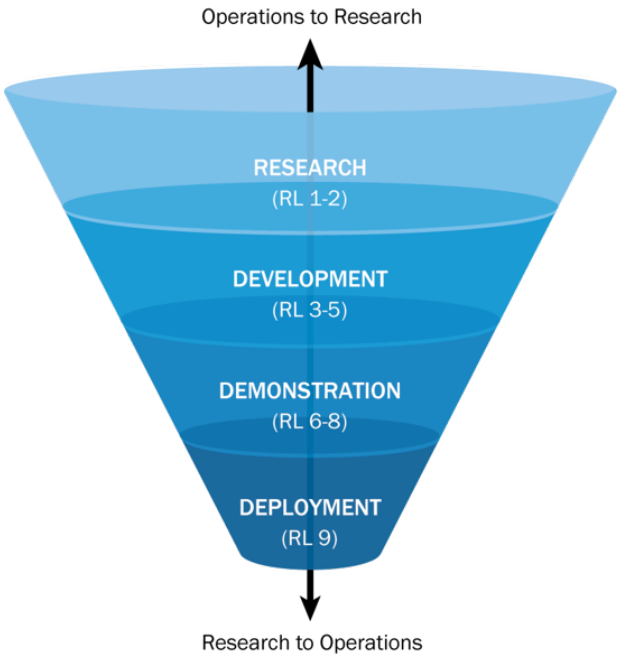
1. Hurricane intensity forecasting, including through deployment of unmanned ocean observing platforms and enhanced data assimilation;
2. Flood prediction, forecasting, and mitigation capabilities;
3. Wildfire prediction, detection, and forecasting.

Introduction

Scientific Infrastructure

The science described in this report is not possible without investments in enabling research infrastructure, including the acquisition and maintenance of "hard" infrastructure, such as extensive observing systems, satellites, ships, aircraft, laboratories, and high-performance computing systems. These critical assets provide the data and tools for NOAA scientists to increase understanding of our Earth systems, provide better forecasts, and inform decisions.

NOAA Transitions Research into Operations, Applications, Commercialization, and Other Uses (R2X)

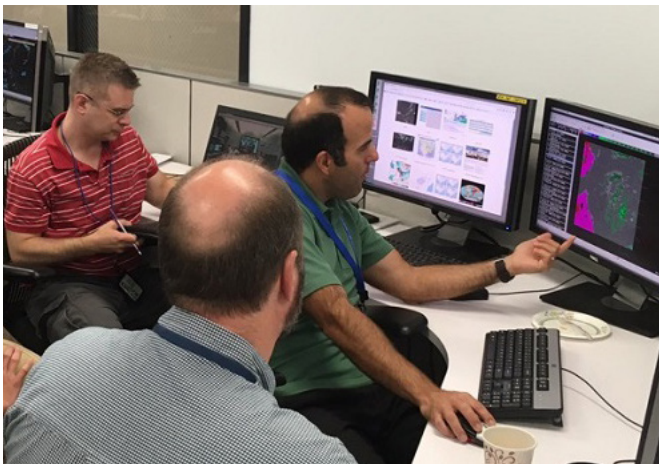


NOAA's testbeds and proving grounds include:

1. Arctic Testbed
2. Aviation Weather Testbed
3. Climate Testbed
4. Coastal and Ocean Modeling Testbed
5. Developmental Testbed
6. GOES-R Proving Ground
7. Hazardous Weather Testbed
8. Hydrometeorology Testbed
9. Joint Center for Satellite Data Assimilation
10. Joint Hurricane Testbed
11. Operations Proving Ground
12. Space Weather Prediction Testbed

NOAA and the Nation extract benefit from NOAA's research when the research results transition into use; consequently, research and development transitions are essential to addressing NOAA's missions. NOAA uses a system of nine readiness levels (NAO 216-105B) to characterize and track the maturity of NOAA scientific projects through research, development, demonstration, and deployment.

Transition plans describe and facilitate the transition of R&D to potential end use, and represent an agreement between researchers and potential recipients. In addition, NOAA's 12 testbeds and proving grounds allow for pre-deployment testing of NOAA's research and development to facilitate the transition into forecasts, warnings, products, services, and decision support.



The Aviation Weather Center hosted the 2019 Aviation Weather Testbed Summer Experiment August 19-23, 2019. Image credit: NOAA.

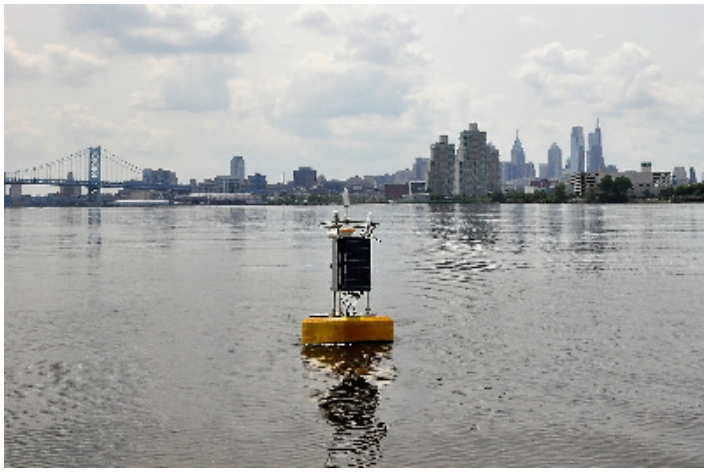
Introduction

Examples of Research Transition

The following activities listed below highlight just a few of the R&D projects that have been selected to move from research to operations, applications, commercialization, or other uses.

Portable buoy for nearshore, real-time current observations

A portable buoy was developed to meet a growing need for a quick deployment, near-surface, real-time coastal currents observation platform. This tool can enable incident responders to predict the fate and trajectory of spilled pollutants, serves as a reconnaissance tool to assess changing tidal currents, and can be used as a real-time currents platform for the Physical Oceanographic Real-Time System (PORTS). Following successful field demonstrations, a transition to operations of the new system was completed during 2019. The system was deployed operationally for the first time in July, 2019 at the Delaware River near Philadelphia, Pennsylvania to meet a request from pilot captains to better resolve complex tidal currents. Resulting measurements will improve existing NOAA NOS tidal current predictions and associated navigational support products at this location. Sites for 2020 potential deployments include the Port of Miami, Florida, the Gulf Coast of Florida, and South Chesapeake Bay, Virginia.



New real-time currents buoy during its first operational deployment (July 2019) in the Delaware River, West of Philadelphia. Photo credit: NOAA/NOS/Center for Operational Oceanographic Products and Services, Katie Kirk

Using machine learning to improve forecasts of excessive rainfall

Forecasters at NOAA NWS are responsible for producing Excessive Rainfall Outlooks, which highlight the potential for flood-inducing rains up to three days in advance. However, the amount of rain that qualifies as "excessive" varies from region to region, and pinpointing the specific areas likely to receive heavy rain is challenging, especially during the summer thunderstorm season. Through support from the NOAA Joint Technology Transfer Initiative, researchers developed a forecast system that uses past forecasts and observations of heavy rainfall, along with machine learning algorithms, to identify the probability of flood-producing rains across the U.S. at forecast lead times of 2-3 days. Close collaboration between the university scientists and NWS staff allowed for this forecast system to be transitioned into operational use, so that forecasters now have an additional tool to bring awareness to areas that are at risk of potentially destructive and deadly heavy rain and flooding.

Introduction

Public-private collaboration to develop user-friendly kits for genetic tracking of fecal-indicating bacteria in the environment

Molecular Microbial Source Tracking (MST) is a suite of 'omics-based assays aimed at detecting, measuring, and tracking bacterial contaminants in environmental samples. NOAA Research is collaborating with the Pall Corporation to transition a variety of MST research assays into user-friendly kits that will run on the Pall GeneDisc Rapid Microbiology thermocycler system. In 2018, NOAA adapted select assays to run in the Pall system and transitioned these GeneDisc-based MST assays to the Commonwealth of the Northern Mariana Islands (CNMI) Bureau of Environmental and Coastal Quality (BECQ), which used the technology to conduct a study on land-based sources of pollution in Saipan from 2018-2019. NOAA is now collaborating with Pall to generate simple-to-use prototype kits that include all reagents and standards in order to further automate analysis of results, and encourage more widespread availability of this MST technology.

Marine sanctuary condition reports use the integrated ecosystem assessment framework

NOAA NOS, in cooperation with many partners, including NOAA Fisheries, develops National Marine Sanctuary condition reports that are used to assess the status and trends of National Marine Sanctuary resources. To improve the approach to determining status and trend ratings, NOAA uses an Integrated Ecosystem Assessment framework, which offers a quantitatively rigorous and repeatable approach to identify and assess indicators for sanctuary resources, driving forces that influence pressures on resources (e.g., commodity prices such as fuel, changing income, import/export dynamics), human activities, and ecosystem services. NOAA released the new condition report for Channel Islands National Marine Sanctuary, and activities are currently underway at Stellwagen Bank, Olympic Coast, Florida Keys, and American Samoa National Marine Sanctuaries and Papahānaumokuākea Marine National Monument. New tools developed by the NOAA co-funded Marine Biodiversity Observation Network (MBON) will provide interactive infographics that provide dynamic information for experts to prepare and update condition reports, and allow data-driven awareness for responding to events. These tools can also be used to support education and outreach products.

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Science Highlights

Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena

NOAA research and development improves the forecasts and warnings that provide accurate and timely information to inform the public about hazardous weather and environmental events. Through a better understanding of weather and climate phenomena, as well as the human perception and behavior in response to risk communication, NOAA science helps to save lives and property.

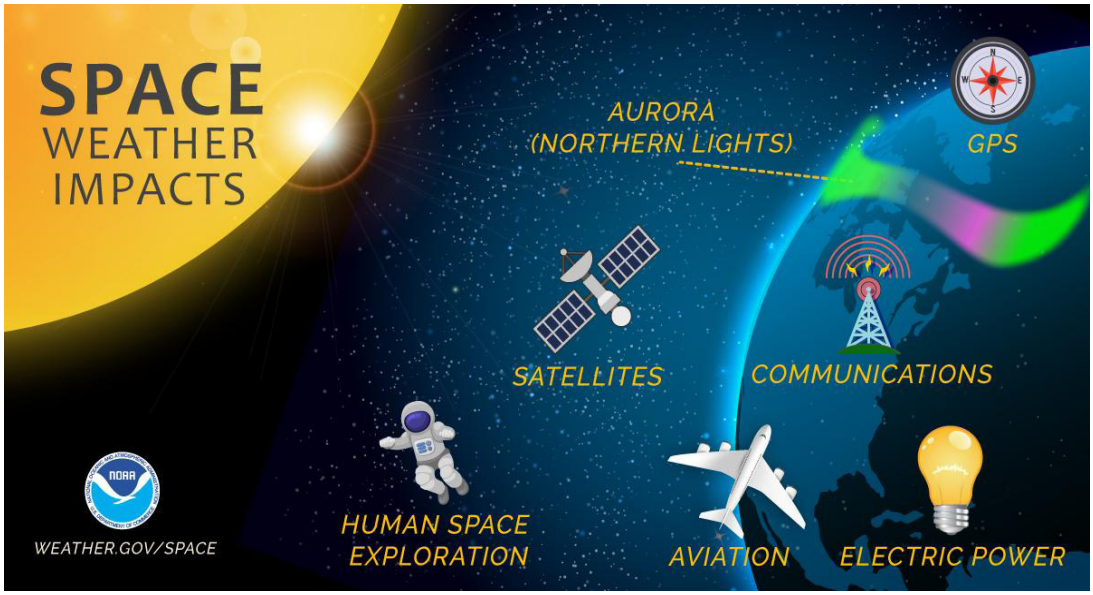
In 2019, NOAA's scientific accomplishments for reducing societal impacts from hazardous weather and other environmental phenomena included the following:

- Improving space weather forecasts so astronauts are ready for exploration
- Listening to solar storms
- Improving communication of forecast uncertainty and risk information
- VORTEX-SE: Insights into the structure and predictability of southeastern US. tornadic storms
- Meteotsunami detection and climatology
- Saving more lives and property with improved timing/path prediction for tornadoes
- New NOAA satellite data are helping improve tool to predict severe Great Lakes snowstorms
- Applying machine learning to improve severe weather forecasting
- New modeling capabilities to advance severe weather predictions within a Unified Forecast System
- New research uses laboratory and airborne field measurements to understand climate and air quality effects of wildfires
- NOAA advancements for subseasonal to seasonal severe weather forecasts
- New research probes the effects of wildfires
- Protecting lives and mitigating flood damage during hurricanes and tropical storms
- Integrating advanced high performance computing to improve forecasts of high impact events like hurricanes
- New tools help communities measure impact of reducing greenhouse gases
- The National Blend of Models forms an accurate basis for forecasts
- Estimating the economic benefits of the tornado warning improvement and extension program
- Integrating probabilistic hazards information into hazard services
- Improving North American heat wave forecasts

Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena

Improving space weather forecasts so astronauts are ready for exploration

With the United States planning to return to the Moon and eventually travel to Mars, astronauts will be venturing outside the protective shield of Earth's magnetic field for the first time since the Apollo era. In anticipation of the accompanying increased vulnerability to energetic proton radiation resulting from solar storms, NOAA is working to improve the accuracy of its forecasts and warnings of such hazardous conditions. Energetic proton radiation can impact human health and the functionality of computer equipment. NOAA has partnered with the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) to support scientific research to advance our predictive capabilities. Research progress was highlighted at NOAA's Space Weather Workshop in April 2019, and NOAA is working with NASA to define the forecasting services needed for upcoming human space exploration missions. These research and service improvements will not only benefit future astronauts, but will also improve satellite operations, which are also impacted by proton radiation, and play a vital role in the nascent commercial space travel industry.



Space weather can jeopardize the technologies we rely on daily. Image credit: NOAA

Listening to solar storms

High school students listening to audio tracks of NOAA satellite data have identified the sounds of solar storms buffeting Earth's magnetic field. The results of a United Kingdom-led citizen science project suggest that the approach of converting physical data into sound signals could help NOAA and other scientists make sense of massive amounts of data from satellites and other instruments. Earth's magnetic shield, which protects against harmful radiation from the sun and more distant sources, is full of ultra-low frequency waves that occur at a much lower frequency than the range of human hearing. By speeding up the audio files so humans could hear—a process called sonification—one year of raw data became six minutes of audio. NOAA scientists gathered data using NOAA's geostationary satellites and made it, including the full audible dataset, publicly available.

Improving communication of forecast uncertainty and risk information

Through a NOAA-funded Verification of the Origins of Rotation in Tornadoes EXperiment-Southeast (VORTEX-SE) grant, researchers are studying risk communication to improve the Weather Enterprise's understanding of expert interpretations and uses of different types of information, especially probabilistic information, in warning decisions. To this end, the researchers are examining concepts of uncertainty and confidence that arise between multiple expert groups, like the Storm Prediction Center, a local Weather Forecast Office (WFO), and their partners in emergency management. Focusing on cool and warm tornado seasons in the southeastern United States, the team is combining different qualitative methods to build new knowledge: how meteorologists at national centers, WFOs, and their core partners conceptualize uncertainty and confidence; and, how these concepts emerge through various interactions and influence risk communication among these groups leading up to and during tornado events. Results from this study may inform changes made to practices of communication of uncertainty information among expert communities.

Members of the public can recieve severe weather alerts through a variety of mediums. Image credit: NOAA

VORTEX-SE: Insights into the structure and predictability of southeastern U.S. tornadic storms

Researchers are using high-resolution surface observations near Verification of the Origins of Rotation in Tornadoes EXperiment-Southeast (VORTEX-SE) storms to associate the magnitude and shape of cold pools of air with the production of tornadoes. One completed case, from April 30, 2017, has shown that the magnitude of the cold pool distinguishes tornadic and nontornadic portions of the line of storms. Ensemble sensitivity analysis has been applied to retrospective High-Resolution Rapid Refresh Ensemble (HRRRE) simulations of specific VORTEX-SE cases to understand what features in the upstream state drive increases in storm rotation later. The team has some initial insights into what improvements can be made to the sampling strategy in future field campaigns to yield the most improvement in forecasts of severe storms.

Meteotsunami detection and climatology

NOAA applied an automated approach to identify meteotsunamis—atmospherically forced ocean waves with characteristics similar to seismic tsunamis—from 125 NOAA tide gauges along the U.S. east coast over a 22 year period, 1996-2017. The study found that meteotsunamis occur frequently (about 25 per year), but the vast majority of them are small, with a wave height less than 1.5 feet. They were found to occur most frequently in the winter and summer months, especially in July, and most often in the Carolinas, northern Florida, and Long Island Sound. Approximately one event per year had a wave height exceeding two feet, which is currently categorized as a potentially impactful event. For example, the meteotsunami observed on June 13, 2013 in New Jersey and along the East Coast reached about two feet and caused several injuries and damage to boats. NOAA also performs this work on the Great Lakes, and NOAA NWS will support ongoing efforts identifying and warning about these potentially hazardous events.

The derecho system which caused the June 13, 2013 meteotsunami as it passes offshore of New Jersey. Photo credit: Buddy Denham

The windsonde team prepares for a balloon launch during a storm in Nebraska in late May. Photo credit: Christian Patterson/University of Oklahoma Cooperative Institute for Mesoscale Meteorological Studies/NOAA/National Severe Storms Laboratory

Saving more lives and property with improved timing/path prediction for tornadoes

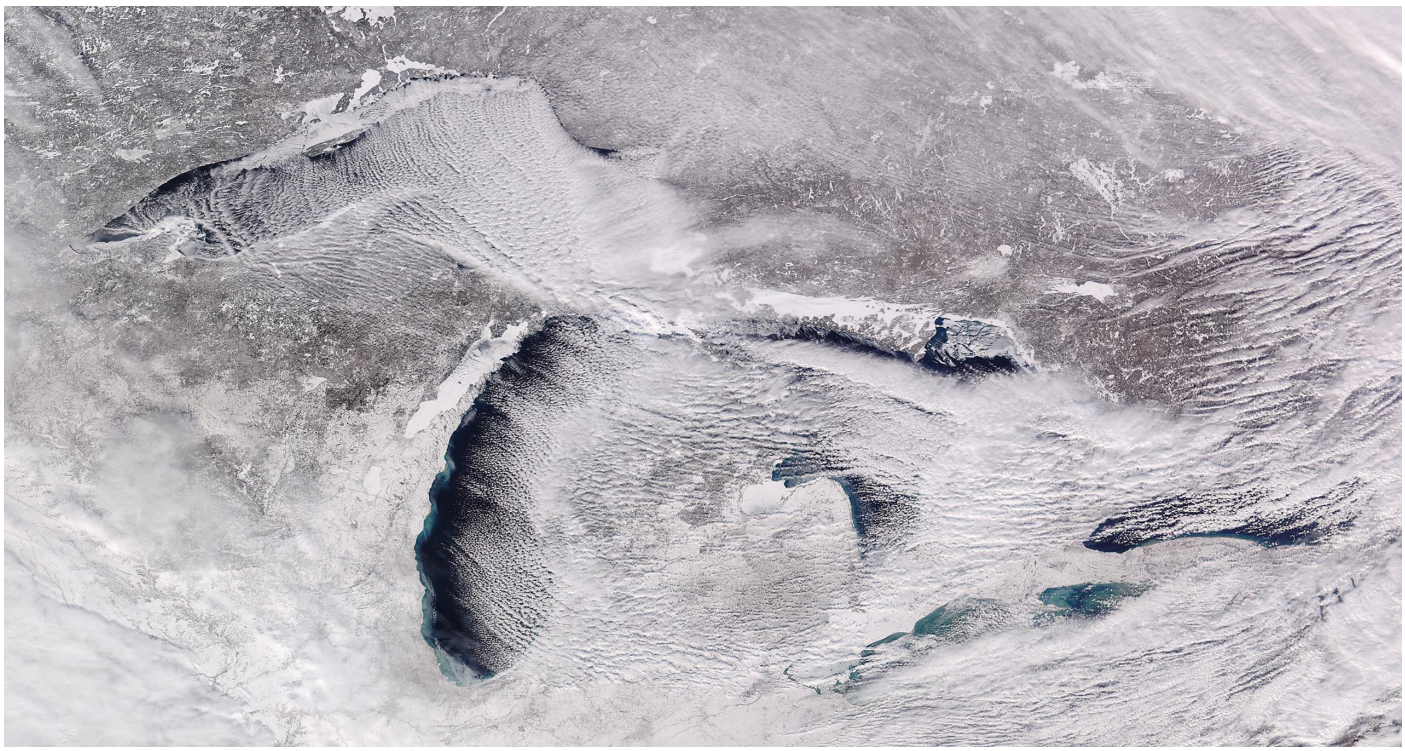
Multiple research teams follow severe thunderstorms to study how factors like wind speed, temperature, humidity and pressure may reveal the small-scale structures in a supercell storm and how it contributes to tornado formation. Targeted Observation by Radars and Unmanned Aircraft Systems of Supercells, or TORUS, involves more than 50 researchers using 20 tools to measure the atmosphere, including unmanned aircraft systems, mobile radars, and NOAA's Hurricane Hunter aircraft. The teams conduct fieldwork in a 367,000-square-mile area of the Central Great Plains. The data the researchers collect will be used to improve conceptual models of supercell thunderstorms. Roughly a dozen radar, ballooning, unmanned aerial vehicle, and ground-based observations teams will travel into the storm, along with a team in a NOAA Hurricane Hunter aircraft flying just outside the storm, to provide a data-driven, multi-dimensional view of each storm system.

Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena

New NOAA satellite data are helping improve tool to predict severe Great Lakes snowstorms

It is notoriously difficult to forecast the location and intensity of lake-effect snow storms in the Great Lakes region. These frequent snow storms are produced by heat and moisture exchanges between the lake surface and overlying atmosphere during outbreaks of cold air from the Arctic. These storms create hazards and socioeconomic impacts on Great Lakes communities, bringing with them heavy snow, blowing snow, reduced visibilities, and hazardous roads. New NOAA satellite data are helping improve predictions of Great Lakes snowstorms. The Lake Effect Nowcasting Tool, created by NOAA NWS and the Cooperative Institute for Meteorological Satellite Studies, leverages the high spatial and temporal resolution of the Geostationary Operational Environmental Satellite-R Series (GOES-R) satellite images with the NWS Next Generation Weather Radar (NEXRAD) and surface snowfall observations to help improve estimates of total snowfall and predictability of snowfall location. The Lake Effect Nowcasting Tool will be applied in real-time during the 2019-2020 winter season at the Marquette, Michigan, National Weather Service office in a research and development setting. By connecting cloud properties obtained from GOES-R to snowfall estimates from ground-based instrumentation, this research enables forecasters to better estimate the impact these lake-effect storms will have on Great Lakes communities.

> *"The Enhanced Lake Effect Nowcasting Tool is a great example of research to operations, as NOAA-sponsored scientists are working directly with NWS forecasters to improve satellite-based snowfall estimates."*
>
> *- Dr. Louis Uccellini, Director, NWS*



Lake-effect snowstorm traversing the Great Lakes region as captured by NOAA-20 VIIRS (true color) on January 27, 2019. Image credit: NOAA

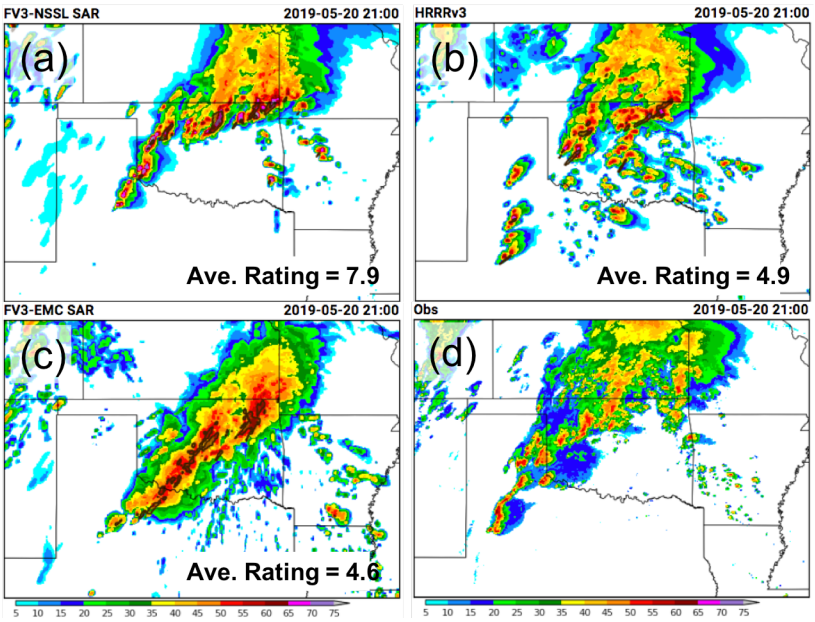
Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena

Applying machine learning to improve severe weather forecasting

NOAA is harnessing the power of machine learning to improve warnings for severe weather and reduce the impacts of those hazards. A recently funded Joint Hurricane Testbed project is exploring the use of machine learning methods to predict rapid intensification of Atlantic basin tropical cyclones. The product, which uses an ensemble of probabilistic machine learning methods, was informally tested during the 2018 Atlantic Hurricane season and was tested during the 2019 Atlantic season with the goal of eventually transitioning it to operations for NOAA NWS.

New modeling capabilities to advance severe weather predictions within a Unified Forecast System

NOAA has initiated a multi-year effort to develop a Unified Forecast System (UFS) spanning local to global domains and sub-hourly to seasonal predictive time scales in order to dramatically improve U.S. operational weather and hurricane forecasting. The UFS uses NOAA's Finite-Volume on a Cubed Sphere (FV3) dynamic core and was implemented operationally for global weather predictions in 2019, but is still being developed for regional storm scale applications. As researchers showed significant results for U.S.-wide storm scale modeling in 2018, they accelerated their efforts in 2019 through the development of a stand-alone-regional (SAR) version of FV3 that saved significant computational resources, enabling more advanced data assimilation for improved short-range forecasts. During the 2019 NOAA Hazardous Weather Testbed Spring Forecasting Experiment (SFE), several agencies ran configurations of SAR FV3 with very promising results. The testbed's preliminary analysis of subjective ratings from this experiment show that a configuration run by NOAA Research performed slightly better than NOAA's operational short-term prediction model (the High Resolution Rapid Refresh [HRRR]), and had the most accurate convective evolution over central Oklahoma for a potential high impact event on May 20, 2019.

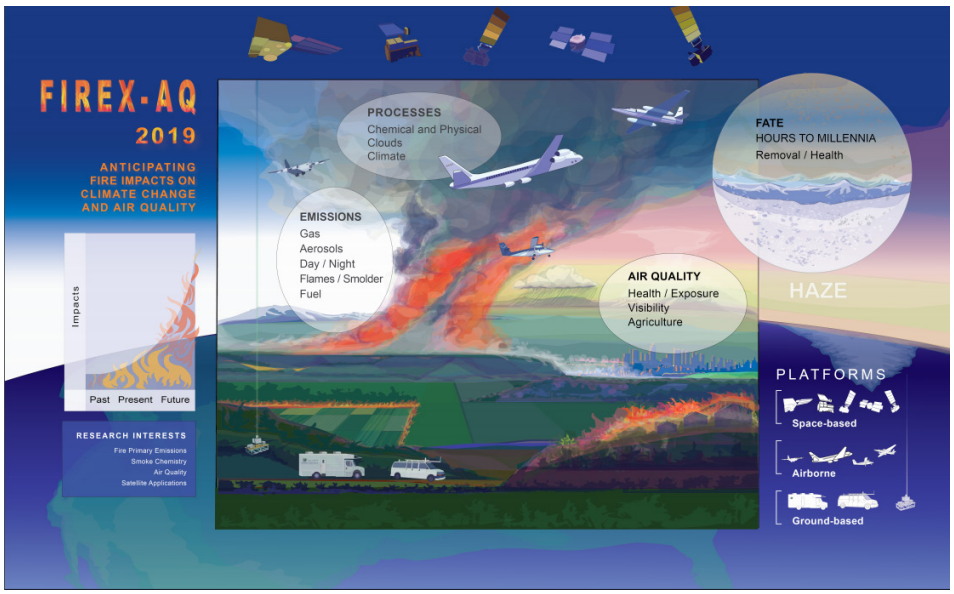


Forecast radar (shaded) and storm rotation (black contours) from versions of SAR FV3 run by (a) NSSL and (c) EMC, (b) the HRRR, and (d) corresponding observations. The forecasts were made a day in advance and are valid at 4pm on May 20th. The average subjective ratings, on a scale of 1 (very poor) to 10 (very good), are indicated at the bottom right. Image credit: NOAA

Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena

New research uses laboratory and airborne field measurements to understand climate and air quality effects of wildfires

Increases in wildfire frequency and intensity in the western United States due to climate change and other factors have raised questions about the impact of biomass smoke on climate and air quality. During the summer of 2019, NOAA and National Aeronautics and Space Administration (NASA) led Fire Influence on Regional to Global Environments and Air Quality, (FIREX-AQ), which brought together scientists from the Department of Energy, Naval Research, the National Science Foundation, the National Academies of Science and 22 U.S. universities to investigate impacts from wildfires and agricultural fires across the continental U.S. The team deployed a highly sophisticated set of satellite, airborne, and ground instruments to investigate smoke from ignition to dispersion. The major airborne platform included NASA and NOAA aircrafts. The 2019 field mission built on laboratory results from an intensive 2016 study of biomass emissions at the U.S. Forest Service Fire Science Laboratory in Missoula, Montana that produced the most detailed characterizations of gaseous and particle species in biomass smoke to date.



NOAA OAR/Earth System Research Laboratory/Chemical Sciences Division and FIREX-AQ partners use an array of instruments. Image credit: NOAA.

NOAA advancements for subseasonal to seasonal severe weather forecasts

NOAA researchers and partners are exploring the development of severe weather forecasts in the subseasonal to seasonal (S2S) time frame. NOAA researchers partnered with scientists at Columbia University and established relationships between the Madden Julian Oscillation (MJO) climate phenomenon and U.S. tornado occurrence. In a related project funded by a NOAA grant, Colorado State University scientists have developed a statistical methodology that in development mode allows skillful weekly forecasts of opportunity based on the MJO, identifying parameters favorable to severe weather as well as actual tornado and hail activity. The experimental forecast model has significant skill in regions such as the Plains and the Southeast, potentially providing stakeholders with valuable extended forewarning (2-5 week lead times) of when and where potentially deadly severe thunderstorm activity is likely to occur. In the future, these efforts could expand and complement severe weather outlooks.

Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena

New research probes the effects of wildfires

In 2017 and 2018, wildfires in the western United States gave rise to some of the highest levels of air pollutants ever seen in the U.S. Particulate matter less than 2.5 micrometers in diameter (PM2.5) and ozone are key regulated air pollutants with known health impacts on people. NOAA-funded University of Washington researchers analyzed existing air quality data, made new observations, and used statistical modeling to better understand the impacts from fires on PM2.5 and ozone concentrations. The team found that PM2.5 reached record levels at times during those two years in Missoula, Montana; Portland, Oregon; Seattle, Washington; and San Francisco, California. Ozone concentrations were also exceptionally high on smoke days, with many cities seeing their highest concentrations in the last two decades. Scientists found that the days with highest PM2.5 levels are not the days with highest ozone levels. Instead, the highest ozone concentrations are usually seen on moderate smoky days, not days with extremely high particulate concentrations. A key goal of the research is to understand the health implications of wildfires at a time when wildfires are increasing in the western United States.

NOAA OAR's Climate Program Office funded research that analyzed air quality data from wildfires. Photo credit: P. Cullis, NOAA

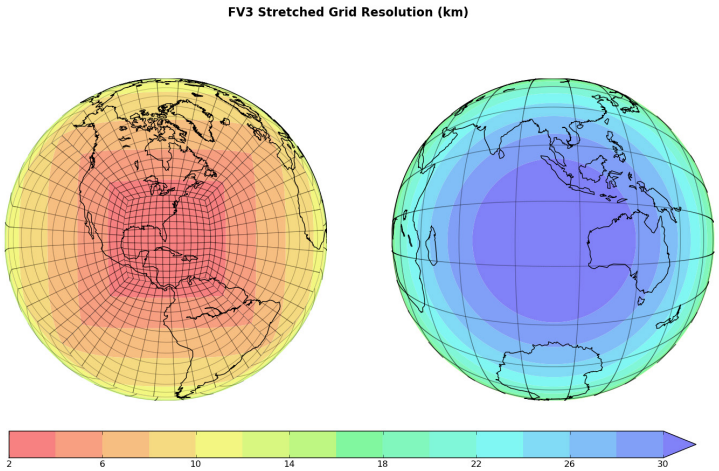
Protecting lives and mitigating flood damage during hurricanes and tropical storms

As part of the Agency Priority Goal effort, the NWS forecasted a High Risk of excessive rainfall and warned of catastrophic flooding three days in advance of Hurricane Florence in September 2018. The excessive rainfall outlook and storm surge inundation mapping were posted prominently on the National Hurricane Center homepage and shared extensively through operational dissemination. This message was repeated and amplified by private sector and media partners. With this amount of lead time, FEMA and States were able to pre-position swift water rescue boats and generators. Catastrophic flooding was observed, and FEMA, State, and local officials were ready to save lives and property. In addition, NOAA NWS provided experimental guidance for a number of national water models including forecast flood inundation extent maps that depicted areas of inundation based on peak forecast streamflow over the next 10 days. Using these flood inundation extents, NOAA NWS coordinated with FEMA to provide them shelter assessment maps, which were produced twice daily starting on 14 September for North Carolina and South Carolina. These products helped to provide additional situational awareness (beyond the 100 and 500 year flood maps FEMA typically uses) as to what shelters would still be accessible given the historical extent of this flood. Shelters were deemed "accessible" and plans were made to utilize each location based on their proximity to the maximum flood inundation extent. NOAA NWS used the experience and data from Florence to help mitigate flooding damage in Texas from Tropical Storm Imelda (2019). These continuing efforts will help with FEMA efforts in getting people to shelters, enable efficient evacuations across flooded road systems, and ensure crowd sourcing is addressed.

Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena

Integrating advanced high performance computing to improve forecasts of high impact events like hurricanes

NOAA NWS researchers use high-performance computing (HPC) systems to help meteorologists and other scientists use satellite imagery and data to improve the accuracy of forecasts, simulate dangerous weather patterns, and create better early warning systems for hurricanes, tsunamis, tornadoes, and other catastrophic weather events. The National Aeronautics and Space Administration (NASA) and NOAA have partnered to build state-of-the-art supercomputing and data services for weather and climate researchers. As a result, scientists improved the architecture for NOAA's recently upgraded flagship weather model, the Global Forecast System (GFS), with the inclusion of a new dynamical core called the Finite-Volume Cubed-Sphere (FV3). Scientific and performance evaluation has shown that the upgraded FV3-based GFS provides results equal to or better than the current global model in many measures. For example, results looked very promising for both hurricanes Michael and Florence in 2018. This upgrade establishes foundational advancements for the future as NOAA improves observation quality control, data assimilation—for example, with new satellites such as Geostationary Operational Environmental Satellite (GOES) and Unmanned Aircraft Systems (UAS) data—and model physics. HPC has enabled the success of GFS FV3 and will continue to be a very important piece of NOAA's multi-hazard research.



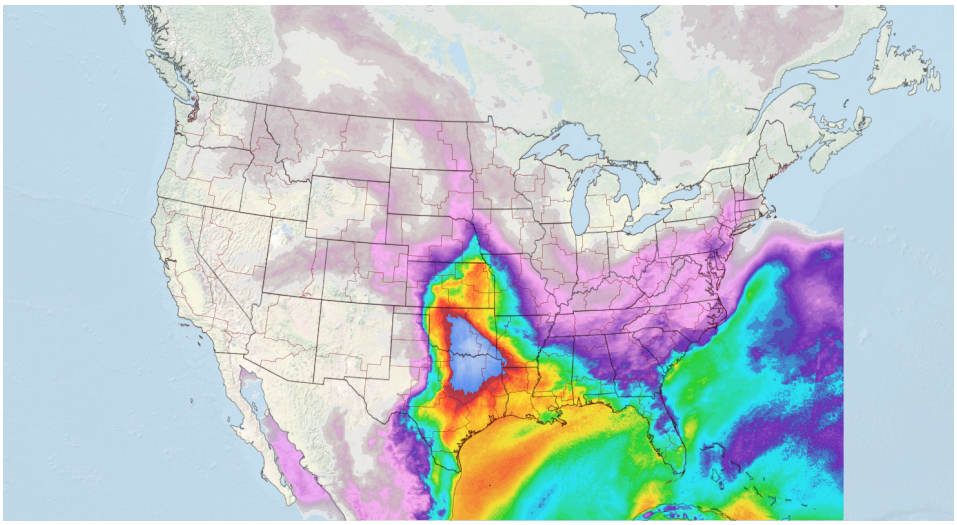
An example of FV3's capability to zoom in on critical weather events: here, the model resolution has been enhanced to better represent hurricanes threatening the southeastern United States. The reverse side is coarser resolution because we are less concerned with that part of the world. By enhancing the resolution only over a part of the earth, we are able to economically get to ultra-high resolution simulations of important areas, or on a potentially-dangerous storm, anywhere around the globe. The colors represent the grid spacing lengths, and the grid is partially outlined in black. Image credit: NOAA

New tools help communities measure impact of reducing greenhouse gases

A new NOAA supported effort is helping communities that are reducing greenhouse gases—such as carbon dioxide (CO_2)—measure the impact of their environmental efforts. Through the CO_2-Urban Synthesis and Analysis (CO_2-USA) project, NOAA Research and its partners are bringing together a network of researchers and stakeholders to build the right combination of instruments, data, and modeling techniques to independently quantify carbon dioxide and methane emissions from specific urban areas. For example, in Boston, Massachusetts the team is analyzing how trees within the city influence greenhouse gas levels, and in Salt Lake City, Utah researchers have outfitted train lines with sensors to measure greenhouse gases and air quality in real time. NOAA and partners also built a next generation emissions inventory with the granularity needed for both atmospheric modeling and policy-making, which is being archived at the Oak Ridge National Laboratory Distributed Active Archive Center under a multi-agency partnership agreement.

The National Blend of Models forms an accurate basis for forecasts

The National Blend of Models (NBM) uses data from models within and outside of NOAA NWS to create a more accurate and consistent starting point for weather forecasts across the United States. The latest version of the NBM is set to be released in 2020 and will improve the NBM's ability to provide aviation, fire weather, water resources, and marine guidance to protect life and property. A few highlights associated with this upcoming release include: (1) enhancements and new products added to the Contiguous United States, Alaska, and Puerto Rico regions to improve precipitation forecasts; (2) addition of statistical uncertainty information for daytime maximum temperatures and nighttime minimum temperatures, 10 meter wind speeds, and 10 meter wind gusts; (3) new additions to aviation guidance to allow airport managers the ability to plan aviation operations through 72 hours; and (4) updates to the NBM text product, which provides NBM guidance at individual locations for various timeframes, including a text message that provides short-term and extended range guidance at stations.



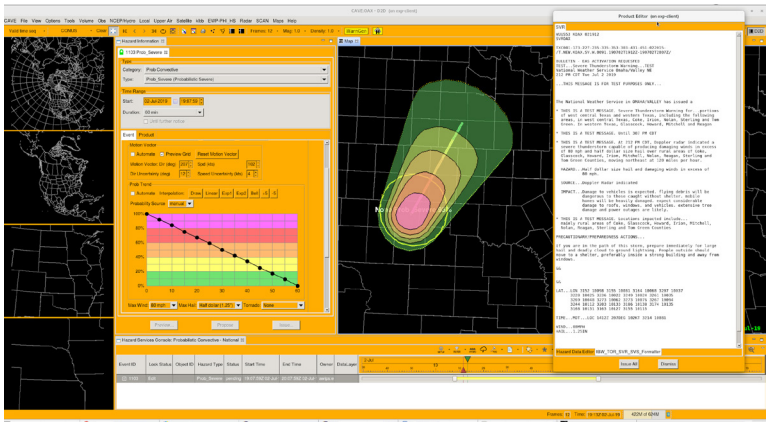
Example of the National Blend of Model's 17-hour guidance for surface-based convective available potential energy used by forecasters for the prediction of convection. Image credit: The NOAA NWS Meteorological Development Laboratory's internal Viewer

Estimating the economic benefits of the tornado warning improvement and extension program

Improved tornado forecasts can reduce economic loss, injuries, and deaths. The Tornado Warning Improvement and Extension Project (TWIEP) improves tornado forecasts by offering the probability that a tornado will happen over the next hour, vastly extending the timeline of information provided to the public as storms approach, and filling the gap between the NOAA NWS watch and warning products. This project identifies two types of decision-makers, vulnerable populations and businesses, and estimates the impact of this new forecast information on tornado casualties and the economy. During 2019, a casualty model was built that identified the populations most vulnerable to tornadoes. Focus groups of businesses revealed their demand for longer lead-times and the potential for them to use probabilistic information in their decisions. In 2020, based on interviews with identified vulnerable populations and econometric modeling of business decisions, the project will generate an estimate of anticipated economic savings from TWIEP information.

Integrating probabilistic hazards information into hazard services

NOAA is testing a Hazard Services Probabilistic Hazard Information (HS-PHI) tool that bridges the current NOAA NWS warning process with recent societal and technological advances. Currently, NWS meteorologists "warn" for the near-term progression of thunderstorm threats by drawing a polygon shape around the storm and downstream, ahead of the anticipated direction of travel. All locations within the polygon represent an area at equal risk of being impacted by the imminent hazard. HS-PHI can help the forecaster generate and visualize moving probabilities of specific thunderstorm hazards over time, based on a continuous stream of forecast and warning information. This provides valuable uncertainty information for end-users to use in their decision-making process. NOAA is also testing a Threats-In-Motion (TiM) concept where severe weather warning polygons update every minute and march forward with the storm threat. TiM provides more meaningful information about the time of a hazard's arrival and departure. When the forecaster workload is high, storms remain continually tracked and warned, and warnings are automatically cleared from locations where the threat is passed. HS-PHI and TiM offer improvements to the current warning paradigm by modernizing the type of information disseminated, not only producing information for the end-user to take immediate life-saving action but also providing more analytical data for enhanced dimensions of service.



The Hazard Services-PHI tool from OAR/Earth System Research Laboratory/Chemical Sciences Division depicting a probabilistic hazard event with its plume of probability (center) the associated Hazard Information Dialog (left) where the forecaster enters the probability trend and other attributes, and the resulting Legacy NOAA NWS warning (right) derived from the probabilistic hazard event. Image credit: NOAA

Improving North American heat wave forecasts

Heat waves are particularly damaging to life, property, and the environment. Accurate forecasting of extreme heat events, particularly on subseasonal (which forecast events up to three months in advance) timescales, is critical for public health preparation as vulnerability to extreme heat has increased over time, especially in urban areas. As a part of Subseasonal to Seasonal (S2S) Prediction Task Force activities funded by NOAA grants, researchers have developed a methodology to seamlessly verify forecasts across weather and S2S timescales applicable to individual and probabilistic forecasts. Experts from national and international modeling centers, including NOAA, are refining the methodology for its potential operational use. In 2019, the project delivered a comprehensive evaluation of heat wave forecasting capability of multiple state-of-the-art, operational forecast models. Results are contributing to understanding and improving forecast model representation of heat waves and diagnosing sources of model forecast errors and skill. Initial results suggest improvements in land surface (e.g., soil moisture and land use/land cover) information for model initialization and parameterization could improve NOAA's operational heat wave forecast capability.

Science Highlights

Sustainable Use and Stewardship of Ocean and Coastal Resources

Our ocean, coasts, and Great Lakes are home to diverse ecosystems, support fisheries and aquaculture, and provide tourism and recreation opportunities. NOAA science seeks a better understanding of the biogeochemical and human processes that impact these resources and informs their conservation, restoration, and sustainable use.

In 2019, NOAA's scientific accomplishments for enhancing the sustainable use and stewardship of ocean and coastal resources included the following:

- New report describes contaminants in Great Lakes mussels
- New tools to monitor harmful algal blooms
- Ocean exploration activities reveal secrets of Blake Plateau
- OceanReports used for aquaculture siting
- Study measures the health of soft-bottom habitats in the Florida Keys National Marine Sanctuary
- Michigan and Ohio communities use Tipping Point Planner tool to improve natural resource decision making and create action plans
- Economic impacts of marine debris on tourism-dependent communities
- Drones to map coastline and nearshore waters
- Engaging the public by live-streaming National Marine Sanctuaries exploration
- Advanced video and analytic technology to survey fish populations, protect habitat
- Using drone technology to obtain critical new estimates of harbor seals in the Pribilof Islands
- Forecasting fisheries in a changing climate
- Northern Bering Sea surveys help set accurate fishing quotas
- Establishing a scientific foundation for blue mussel offshore aquaculture in the southern New England
- Salmon may lose the ability to smell danger as carbon emissions rise
- Seasonal-to-interannual forecasting for the ocean and marine species on the Northeast U.S. Shelf
- Understanding the effects of environmental change on Pacific cod
- NOAA study shows ports that benefit most from NOAA's Precision Navigation Program
- Unraveling the story of salmon in the Pacific and Atlantic
- New tools to track oil spills, improve response
- Saildrones help monitor fisheries and changing ocean conditions
- Four-month coral bleaching heat stress outlook
- Sea Grant teams up with citizen scientists to improve coastal preparedness
- Understanding decisions to participate in oyster aquaculture in Maryland
- Environmental assessment of Bristol Bay, Alaska

Sustainable Use and Stewardship of Ocean and Coastal Resources

New report describes contaminants in Great Lakes mussels

As part of a multi-agency effort of the Great Lakes Restoration Initiative, a new NOAA report documents the levels and distribution of contaminants of emerging concern (CECs) in mussels from the Great Lakes. CECs found in water, sediment, and biota are often unregulated, and their environmental fate and toxic effects are poorly understood. These include pesticides, hormones, flame retardants, pharmaceuticals, personal care products, and chemicals found in household and industrial detergents. Researchers detected these contaminants at sites distant from known sources of pollution. The team is using a variety of health metrics to assess the impacts of the contaminants on mussel health. Given their limited mobility, as well as their limited ability to metabolize chemical pollutants, these mussels serve as indicators to monitor the health and water quality of the Great Lakes.

NOAA divers (Beau Braymer - left and Ed Johnson - right) prepare to collect invasive mussels from the bottom of Lake Michigan with topside support from benthic ecologist Ashley Elgin. Scientists and staff from NOS/National Centers for Coastal Ocean Science and OAR/Great Lakes Environmental Research Laboratory have worked collaboratively since 1992 monitoring chemical contamination across the Great Lakes. Photo credit: NOAA

New tools to monitor harmful algal blooms

Harmful algal blooms (HABs) pose a growing threat to human health and the ecology and economy of the West Florida Shelf. In 2018, a massive HAB occurred in this region and caused widespread mortality of fish and wildlife. This HAB created a human health hazard due to aerosolized toxin from the dinoflagellate *Karenia brevis*, which was the main species responsible for the bloom.

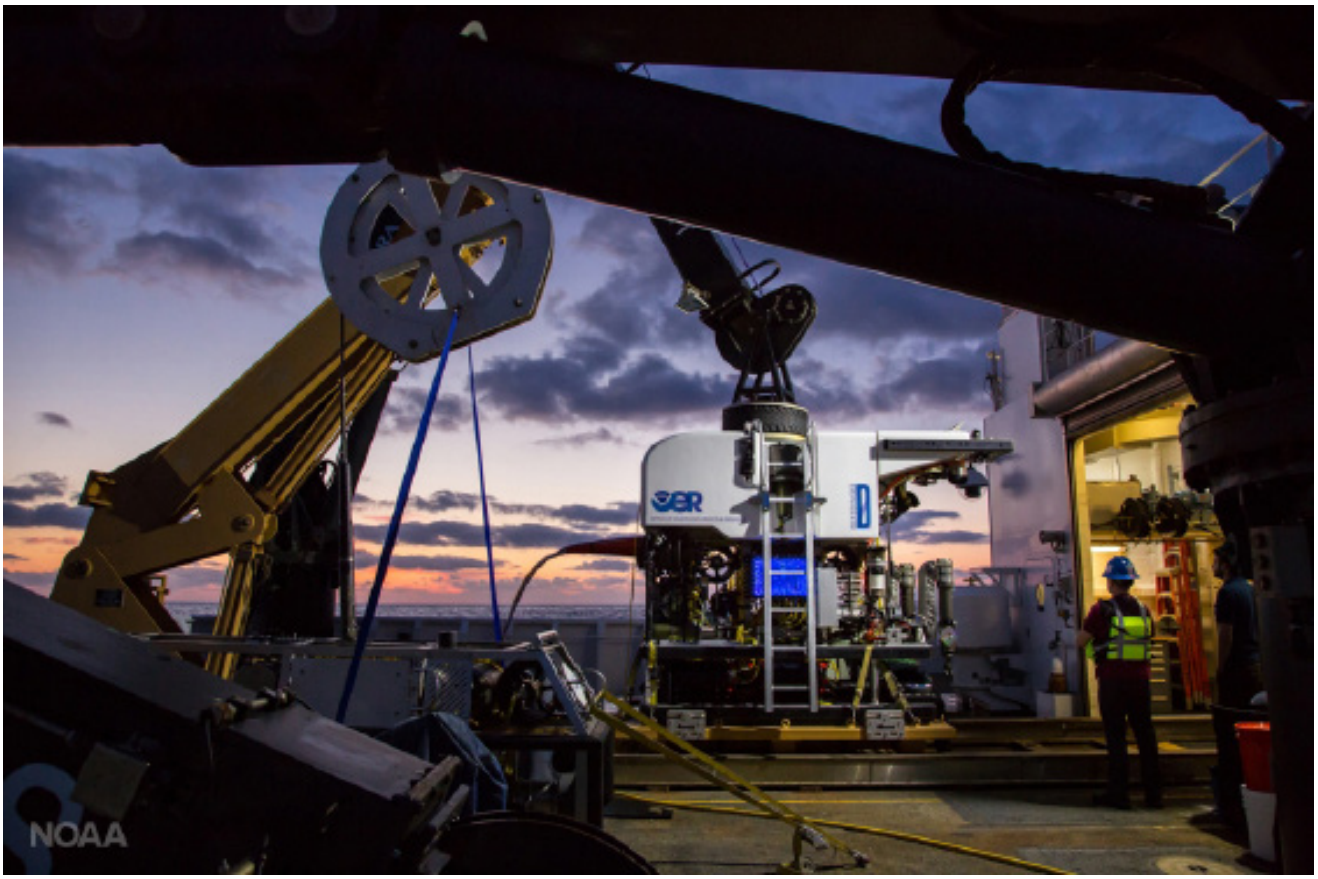
Satellite products showed the areas of extremely high bloom density and the explosive growth of the bloom in July of 2018, until it covered more than 100 miles of the Florida coast. In addition, using extensive, new oceanographic data from glider-mounted instruments and results from computer modeling, NOAA NOS-funded researchers found an additional patch near the sea bottom offshore of Clearwater Beach, which modeling indicates may have come onshore to add to the bloom in Pinellas County. NOAA NOS HAB Event Response projects aided Florida organizations in quickly mobilizing additional sample collection and analysis during the bloom and supplemented data available on changes in the bloom's severity, duration, and location to mitigate its impacts on public health, coastal economies, and wildlife.

As part of its coordinated, nationwide program, NOAA has been developing satellite-based monitoring capabilities to detect and track existing blooms, as well as forecast future ones. This information will provide local authorities and communities with timely information for planning purposes as well as for health warnings and coastal condition updates. The approach is proving to be effective for detecting *Karenia brevis* HABs, and will assist NOAA's monitoring and forecasting system to help Florida communities deal with these blooms.

Sustainable Use and Stewardship of Ocean and Coastal Resources

Ocean exploration activities reveal secrets of Blake Plateau

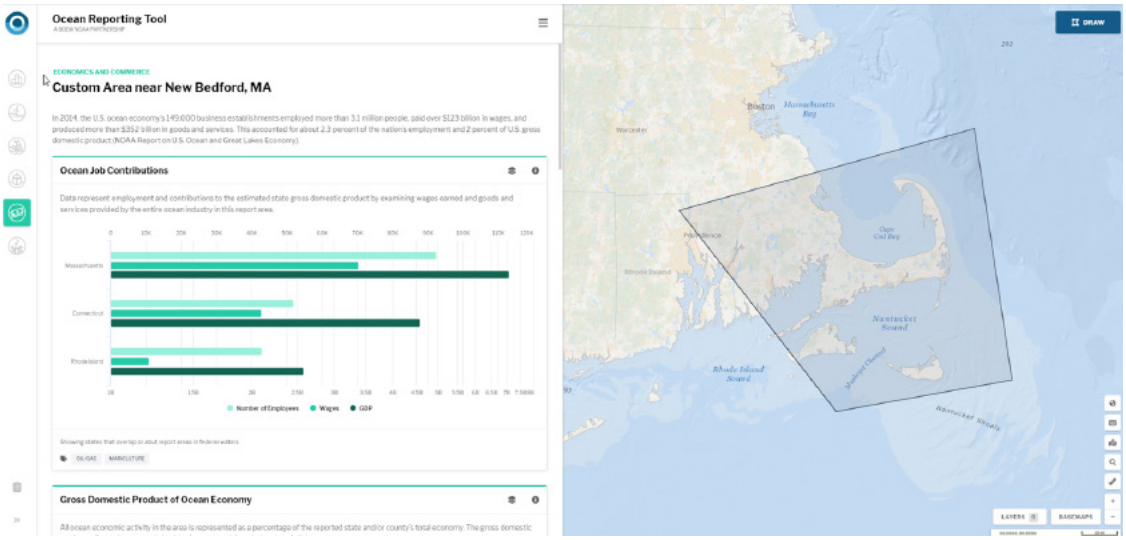
Over the last two years, NOAA Research and its partners have fundamentally changed our understanding of the Blake Plateau on the southeastern United States continental margin. Through bathymetric mapping and visual surveys of this poorly explored area, scientists on recent expeditions have encountered previously unknown features, including extensive, dense populations of the cold-water, reef-building coral *Lophelia pertusa*. Some of these findings were in areas of the plateau previously believed to be flat, featureless, and composed primarily of soft sediment. This work is also credited with confirmation of the largest deep-sea coral reef habitat documented in U.S. waters to date. The location of these features beneath or adjacent to the Gulf Stream, one of the most studied currents in the world, highlights the importance of extending bathymetric mapping coverage within the U.S. Exclusive Economic Zone (EEZ) in support of Seabed 2030 and NOAA's goal to fully map and characterize the U.S. EEZ. Data from these expeditions will help improve our understanding of the deep-ocean habitats of the U.S. continental margin and the connections between communities throughout the Atlantic Basin and, pending further analysis, could inform fisheries management decisions.



The remotely operated vehicle Deep Discoverer (D2) was used to image unexplored areas of the Blake Plateau, Blake Ridge, Blake Escarpment, submarine canyons offshore of North Carolina. Photo credit: NOAA

OceanReports used for aquaculture siting

The new OceanReports web tool provides users with specialized "ocean neighborhood" analyses, including maps and graphics, by analyzing more than 100 ocean datasets instantaneously. Developed by NOAA and the Bureau of Ocean Energy Management, this tool allows users to draw custom areas within the U.S. Exclusive Economic Zone—the area of ocean in the United States' jurisdiction, which extends 200 miles offshore—and get detailed information about habitats and species, industries in the area, potential hazards such as undersea cables or shipwrecks, economic value of ocean commerce, and other detailed oceanographic information.



OceanReports web tool. Photo credit: MaromeCadastre.gov

Study measures the health of soft-bottom habitats in the Florida Keys National Marine Sanctuary

NOAA NOS scientists completed a study of soft-bottom habitats in offshore areas of the Florida Keys National Marine Sanctuary (FKNMS). The study will help inform the sustainable management of the sanctuary, which is important to the region's environmental and economic health. While the area is well known for coral reefs and extensive seagrass beds, soft-bottom sediments are very common. These sediments support diverse communities of bottom-dwelling (benthic) invertebrates that play vital roles in the decomposition of organic matter, nutrient cycling, and energy flow to higher levels of the food chain. The sediments also represent an important sink for chemical contaminants, and the condition of the benthic community can provide a reliable and sensitive indicator for evaluating the biological significance of sediment-associated stressors. Although some of the sediment toxicity assays indicated a positive (toxic) response, sediment concentrations of trace metals, hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs) were below the upper values for sediment quality guidelines. Hence, the observed toxicity in these samples was likely caused by other, unmeasured stressors or confounding factors. Otherwise, the results of this study suggest that the sediments and overlying waters in the surveyed (offshore) area of FKNMS seem to be in good condition with respect to dissolved oxygen, targeted contaminants, total organic carbon, and benthic species richness, diversity, and abundance.

Michigan and Ohio communities use Tipping Point Planner tool to improve natural resource decision making and create action plans

Illinois-Indiana Sea Grant's Tipping Point Planner team helped two communities in Michigan and Ohio develop action plans to protect natural resources. For local planners, balancing community growth and environmental health can be a challenge. Putting down roads, building along waterways, or converting prairies to farmland puts stress on local ecosystems—sometimes so much that it can trigger rapid and potentially irreversible shifts in how they function. When communities are armed with science-based environmental limits, or tipping-points, they can identify critical areas requiring protection or restoration to improve watershed ecosystem health. Illinois-Indiana Sea Grant's Tipping Point Planner is a web-based decision-support system to explore policy and management interventions to keep aquatic ecosystems from reaching critical tipping points and moving to unstable conditions. The Tipping Point team updated the decision support system, redesigned the website, and conducted two community programs in Michigan and Ohio. Each meeting series included an education and vision session with local stakeholders and action-planning meetings with steering committees composed of local experts. The Tipping Point Planner team collaborated with the Au Gres, Michigan, and Perrysburg, Ohio communities to improve land-management decision-making and restoration by targeting nutrient loading and land use practices that impact Great Lakes food webs, algal blooms, and tributary fishery values. As a result of these efforts, 113 participants used the Tipping Point Planner decision-support tool to evaluate ecosystem services and these two communities developed action plans to guide conservation and management of ecological resources.

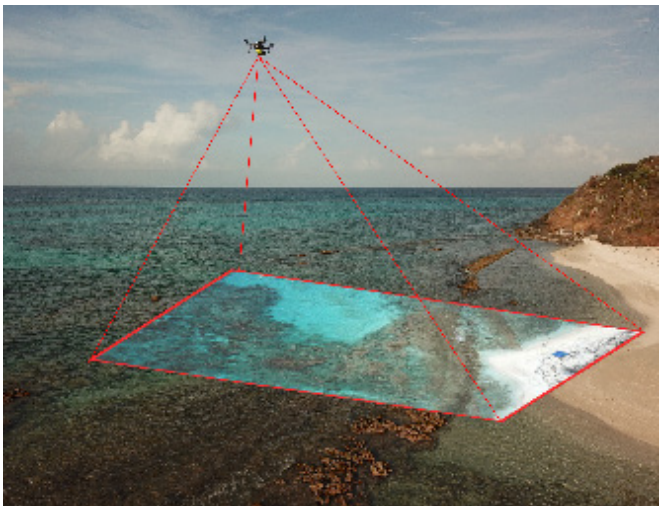
Illinois-Indiana Sea Grant professionals work with members of the Perrysburg, Ohio community to utilize the Tipping Point Planner. Photo credit: Illinois-Indiana Sea Grant

Economic impacts of marine debris on tourism-dependent communities

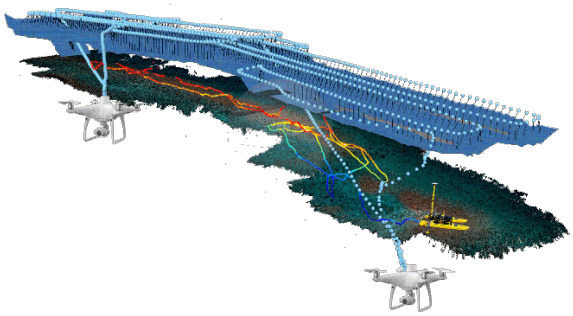
NOAA NOS funded a regional pilot study to evaluate two types of economic impacts that result from doubling and nearly eliminating marine debris on beaches: the loss or gain of recreational value to beach visitors, and the economic impact from reduced or increased spending on beach visits in four selected coastal areas across the contiguous United States. The four study areas were Gulf of Mexico beaches in Alabama, Atlantic Ocean beaches in Delaware and Maryland, Lake Erie beaches in Ohio, and Pacific Ocean beaches in Orange County, California. The study revealed that doubling the current amount of marine debris on beaches within the study areas would decrease the number of days visitors spend on those beaches, which would result in fewer tourism dollars spent, and translate into a decrease in local jobs. Conversely, reducing the current amount of marine debris to almost zero would result in more tourism dollars spent, and translate into an increase in local jobs. In addition to improving our understanding of the economic impact of marine debris, the results from this study may inform the prioritization of areas where prevention and removal efforts may be needed.

Drones to map coastline and nearshore waters

NOAA NOS scientists, in collaboration with Oregon State University, Wayne Wright Consulting, and local partners, used drones and photogrammetric software to map land elevations and water depths around St. Croix in the U.S. Virgin Islands and Santa Cruz Island, California. Drones may offer an efficient and accurate way to map coastal regions that are difficult to access, providing many organizations the photographs, elevation, and depth data needed to inform coastal planning and management decisions. Data from these efforts are being used to identify optimal platforms, payloads, and parameters to define the environmental and operational limitations, and to better understand how drone technologies complement and advance NOAA's existing seafloor mapping capabilities.



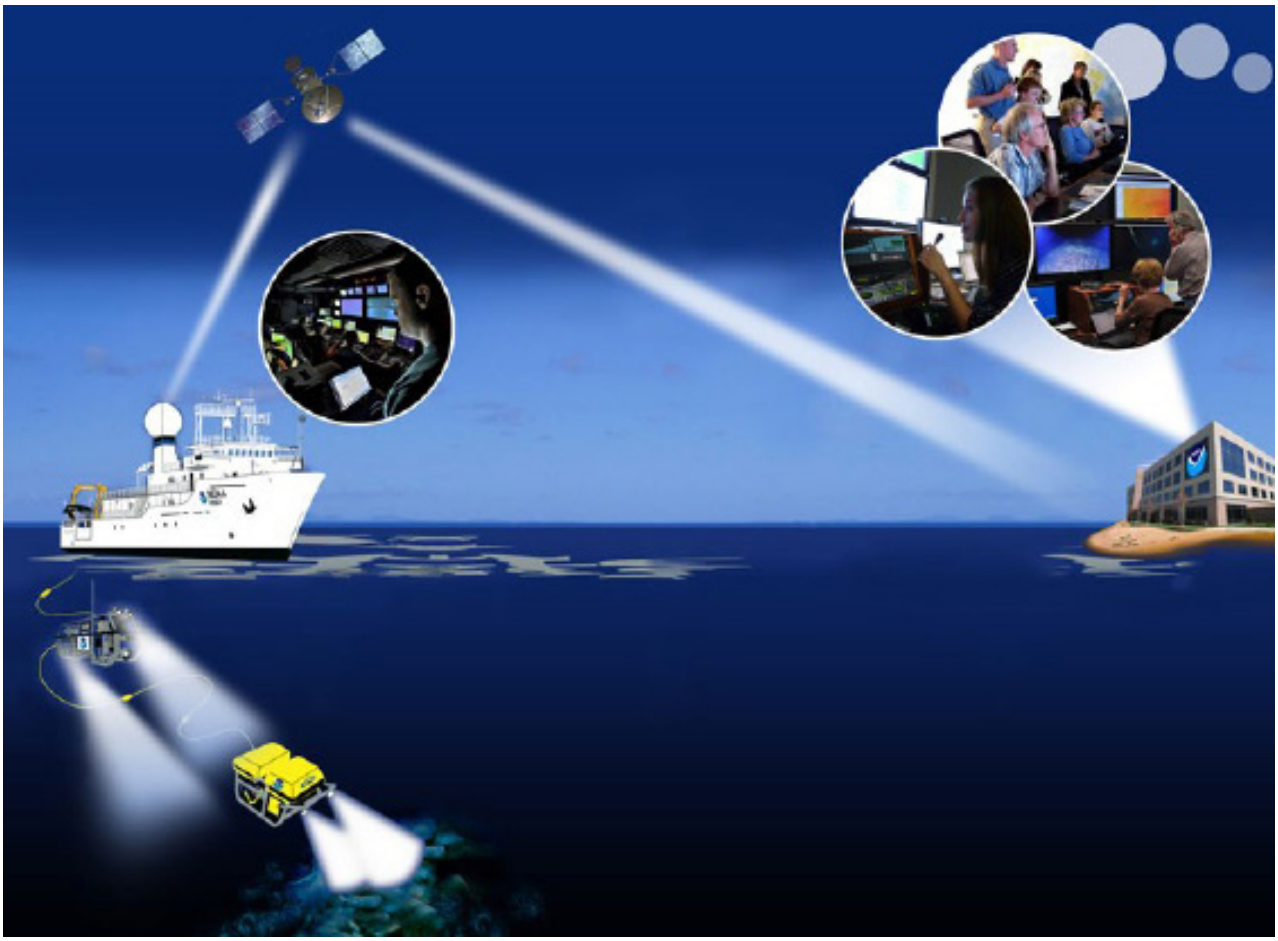
This figure shows an aerial drone collecting photographs along the coast of St. Croix. These photographs (along with photogrammetric software) were used to derive depths for this nearshore area. Depth data in nearshore areas are challenging, dangerous, and expensive to collect using conventional technologies. Aerial drones combined with photogrammetric software have the potential to fill this data gap safely and efficiently. Image credit: NOAA and Oregon State University



This figure shows the integration of different data streams from aerial and surface drones to map nearshore areas. The light blue dots show where the aerial drone collected photographs, and the dark blue polygons show the footprint of these photographs. Overlapping photographs were stitched together using photogrammetric software to create a single photomosaic and calculate seafloor depths. The rainbow lines show where the surface drone collected depths to evaluate the accuracy of these photogrammetric products. Image credit: NOAA and Oregon State University

Engaging the public by live-streaming National Marine Sanctuaries exploration

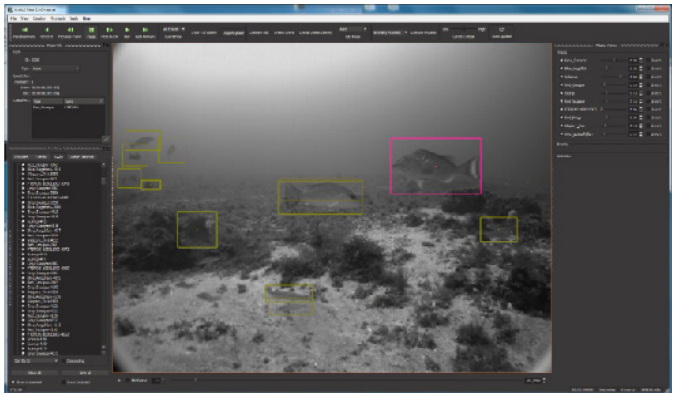
In 2019, NOAA and partners live-streamed the exploration of seven sanctuary sites, engaging broad audiences in ocean discovery using telepresence technology. These missions represent the first telepresence-enabled observations of a number of sanctuary resources, including the first ever observation of mesophotic coral spawning in Flower Garden Banks National Marine Sanctuary. Major science goals include seafloor mapping, characterizing deep-sea biological communities, and assessments of key archaeological sites. With the help of partners from Ocean Exploration Trust, Global Foundation for Ocean Exploration, and Woods Hole Oceanographic Institution, more than 8,500 square kilometers within and adjacent to sanctuary sites were mapped during FY19 cruises. In addition to meeting science goals, these cruises promoted public engagement in sanctuary exploration through ship-to-shore communication events with scientists, live broadcasts from sanctuary sites, and live streams of underwater footage. Live feeds of sanctuary exploration were viewed by more than 23,000 people, and more than 4,600 people engaged with scientists via ship-to-shore connections. Telepresence-enabled exploration took place this year in Thunder Bay, Greater Farallones, Cordell Bank, Monterey Bay, Stellwagen Bank, and Flower Garden Banks National Marine Sanctuaries as well as the National Marine Sanctuary of American Samoa.



Engaging the public by live-streaming National Marine Sanctuaries Exploration. Image credit: NOAA OAR/Office of Ocean Exploration and Research

Advanced video and analytic technology to survey fish populations, protect habitat

NOAA Fisheries is continually developing new methods to better collect and process data from cameras and other technologies used to survey fisheries stocks in habitat where trawl surveys are not possible. Historically, cameras with restricted fields of view have only been able to image a small portion of the environment, potentially biasing the data they produce. NOAA Fisheries has now developed a spherical camera system (SphereCam), with a 360 degree field of view that improves understanding of large schools of fish by imaging a larger area, recording habitat data, and accounting for statistical biases with video-count data. Next generation systems are being designed with improved cameras/sensors and computing to handle high-volume video streams. To account for the large volume of data collected from camera images and video, NOAA partnered with academia and private industry to develop an open-source, modular software toolbox that uses machine learning and computer vision to optimize annotation of image data. The Video and Image Analytics for a Marine Environment (VIAME) system is an end-to-end open source software system that objectively processes underwater and aerial survey imagery. VIAME is currently being used by NOAA Fisheries to identify and measure walleye pollock, assist with processing scallop survey data, facilitate Gulf of Mexico reef fish video surveys, and assist with bottomfish video survey data in Hawai'i.



Example of analysis using VIAME during a Southeast Fisheries Science Center workshop. This image shows detections and identifications of multiple species in one of a sequence of images using a detector trained using VIAME's deep learning algorithms. Photo credit: NOAA Technical Memorandum NMFS-PIFSC-83

Using drone technology to obtain critical new estimates of harbor seals in the Pribilof Islands

Since the summer of 2018, NOAA Fisheries has collaborated with the Aleut Community of St. Paul Island Ecosystem Conservation Office and the Duke University Marine Robotics and Remote Sensing Laboratory to obtain critical new estimates of harbor seals in the Pribilof Islands, Alaska. This small stock of harbor seals is an isolated population in the Bering Sea that has been poorly studied and monitored. In 2018, researchers conducted the first ever comprehensive aerial survey of Pribilof Island harbor seals, using two advanced technology drone platforms. Researchers evaluated the technologies and analyzed the counts for incorporation into the draft 2019 Alaska Marine Mammal Stock Assessment Report. In total, 229 harbor seals were counted during the 2018 Pribilof Island survey. Although harbor seals are not numerous in the area, they are an important indicator of marine ecosystem health. Harbor seals are a key part of an ecosystem that has sustained the Aleut community since the Pribilof Islands were permanently settled in the late 1700s. The drone survey technology has proven extremely useful for monitoring such a remote seal population. In 2019, the monitoring was operationalized and the Aleut Community of St. Paul is leading the efforts to monitor this locally important species.

Forecasting fisheries in a changing climate

Changing climate and ocean conditions present new challenges to our ability to sustainably manage our nation's valuable fisheries. NOAA scientists are conducting and using new research that takes into account the changing climate and ocean conditions to inform fisheries management decisions.

- NOAA Fisheries published recommendations for how to manage shifting species distributions and changing productivity, two major impacts of changing climate and ocean conditions. The recommendations suggest six key steps: detecting changes, understanding mechanisms of changes, evaluating risks and priorities, conducting assessments and developing forecasts, communicating advice, and making management decisions. For each step, the team identified challenges and provided recommendations to address those challenges. These recommendations are described in a NOAA Technical Memorandum and are designed to help fishery managers respond to changing climate and ocean conditions and improve stewardship of our Nation's living marine resources (LMRs).
- Over the last two decades, the productivity and distribution of many LMRs within the U.S. Northeast Shelf have been changing as the shelf ocean waters warm faster than any other marine region within the United States. In 2019, NOAA Research published laboratory results suggesting that the northern stock of black sea bass will continue to shift poleward as the ocean continues to warm. Scientists found that sea bass perform optimally at water temperatures of about 24 degrees Celsius (C); at higher temperatures, the fish experience metabolic performance declines. U.S. Northeast Shelf ocean waters are projected to increase above 24 degrees C over the next 80 years. In addition to the black sea bass research, NOAA is assessing how ocean changes will affect other populations of valuable fisheries including spiny dogfish and squid.

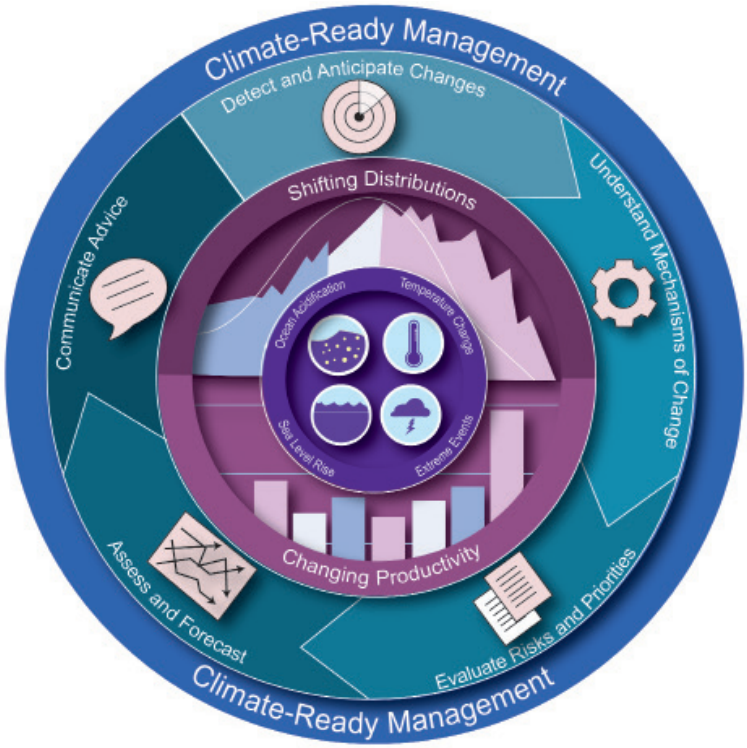


Image credit: Karp et al. 2019, ICES Journal of Marine Science, 76(5):1305-1315

Northern Bering Sea surveys help set accurate fishing quotas

In 2019, NOAA Fisheries collected data to be used to set sustainable fishing quotas for Alaska fishing communities in 2020 with the completion of its 34th annual southeastern Bering Sea shelf bottom trawl survey and its third full survey of the Northern Bering Sea. As in 2018, the eastern Bering Sea had one of its warmest winters on record with the maximum sea ice extent occurring in late January, months earlier than the long-term average (late March-early April). By early summer, sea surface temperatures in the northern Bering Sea were up to seven degrees Celsius above normal as all of Alaska experienced a heat wave that broke temperature records. Once again the colder pool of water normally covering the middle shelf was not significantly present in the southeastern survey area. At the same time, scientists and residents of the Bering Strait region reported increased numbers of young dead seals and walruses washing up on the beaches. There were also reports of increased numbers of dead or dying seabirds observed in the region. During the northern survey of fish and crab resources, scientists documented continued presence of large numbers of Alaska pollock and Pacific cod and significant declines in Arctic species typically encountered in the region relative to a previous survey in 2010. Without the increased understanding of fish stock condition and distribution, resource managers would have had to set much more conservative fishing quotas. A key part of this effort was continued outreach to local communities in the Bering Strait Region, the commercial fishing industry, and resource managers to keep them informed of survey activities and provide current information of how warm conditions in the Arctic are impacting the distribution of fish and crabs and marine foodwebs.

NOAA Ship REUBAN LASKER. Photo credit: NOAA

Establishing a scientific foundation for blue mussel offshore aquaculture in the southern New England

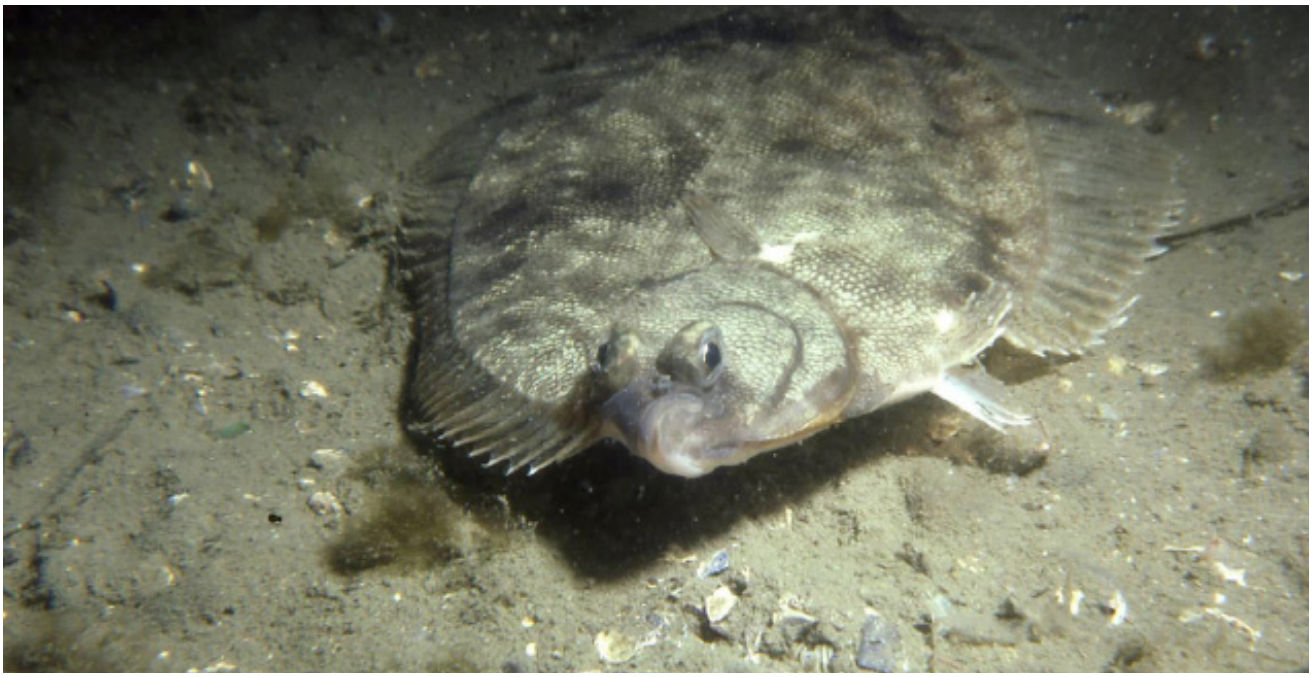
NOAA Fisheries scientists are looking at the scope and scale of the opportunity for domestic mussel production in the U.S. Exclusive Economic Zone off southern New England. Scientists have created a habitat suitability assessment using existing monitoring data, which showed that most locations on the southern New England shelf are, at some depth, suitable for blue mussel cultivation—at least in terms of temperature and food availability. NOAA partnered with Salem State University to "ground-truth" assumptions about suitable habitats using ship-board mussel filtration and feeding measurements at their experimental mussel farm off the coast of Massachusetts. The NOAA team has begun extending the habitat assessment approach to explore the potential for sea scallop aquaculture in coastal Maine. NOAA is anticipating new seafood cultivation opportunities, and providing science products to promote and diversify U.S. aquaculture.

Salmon may lose the ability to smell danger as carbon emissions rise

NOAA Fisheries research showed the potential consequences of ocean acidification on one of the most iconic fish of the Pacific Northwest, salmon. Salmon depend on their sense of smell to avoid predators, sniff out prey, and navigate to their spawning grounds. Researchers from NOAA Fisheries and the University of Washington found that the coho salmon's ability to process and respond to smells is affected by higher levels of carbon dioxide in the water, which causes a decrease in the water pH in a process called ocean acidification. Behavioral and neural tests demonstrated that, in higher carbon dioxide conditions and lower pH, fish could likely smell odors—such as those indicating a predator attack—but the fish did not translate the smell into an appropriate behavioral response.

Seasonal-to-interannual forecasting for the ocean and marine species on the Northeast U.S. Shelf

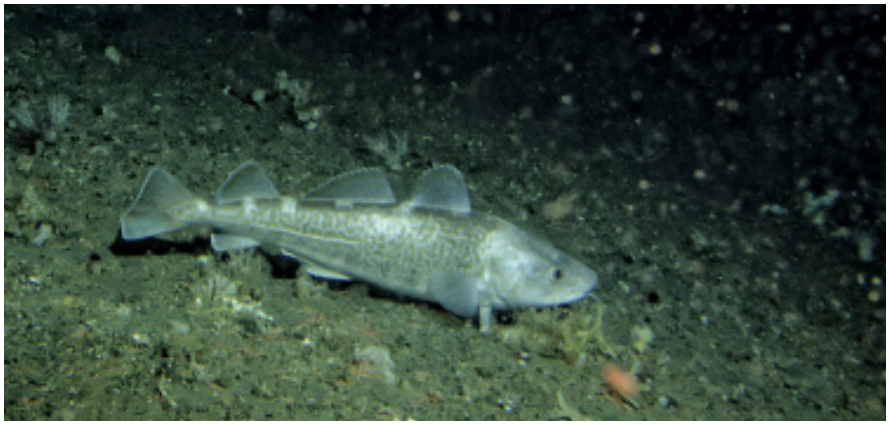
The Northeast U.S. Shelf (NES) Large Marine Ecosystem supports some of the most commercially valuable fisheries in the world and has experienced dramatic ecosystem change in response to fishing pressure, climate variability, and climate change. The combined effects of these changes create a huge challenge for fisheries stock assessment in this region. The stock assessment forecast has been typically based on the biology of the fish and is uncertain. Incorporating physical environmental variables—such as ocean temperature—into the stock assessment population model and subsequent forecast could improve model performance and reduce uncertainty in future population size. A project team participating in the NOAA Marine Prediction Task Force is working on developing a seasonal-to-interannual statistical prediction system (3–36 month time scale) for ocean temperatures on the NES. The approach is tailored to NOAA's needs for fisheries stock assessment.



Winter flounder (Pseudopleuronectes americanus) abundance has declined in the southern New England - Mid Atlantic region over the last 30 years and studies suggest that warming presents a challenge to recovery of this stock. Photo credit: Jerry Prezioso, NOAA/Northeast Fisheries Science Center

Understanding the effects of environmental change on Pacific cod

Two studies by NOAA Fisheries promote the sustainability of the Pacific cod fishery in Alaska by understanding the impacts of ocean acidification and warming on cod larvae. In a laboratory study, researchers found that two-week-old cod larvae reared at elevated carbon dioxide (CO_2) levels were smaller than larvae reared at current CO_2 levels. However, the research also found that by five weeks of age, the CO_2-exposed fish seemed to have recovered from their slow start. In another study, researchers tracked the impacts of the three-year marine heatwave, known as the "Warm Blob," which occurred from 2014-2016. New laboratory data suggest that marine heatwaves can significantly reduce the habitat quality of Pacific cod spawning grounds, while field studies using nets and baited underwater cameras tracked the abundance of juvenile fish. These researchers are now partnering with colleagues at Oregon State University to model the multi-faceted impacts of increasing temperature and CO_2 levels on the survival and distribution of young Pacific cod to predict long-term changes in recruitment potential in this critical fishery species.



Pacific cod. Photo credit: NOAA NMFS/Alaska Fisheries Science Center

NOAA study shows ports that benefit most from NOAA's Precision Navigation program

NOAA NOS is conducting a socio-economic study to determine the ports that are most likely to benefit from adopting Precision Navigation, a tool that integrates real-time and forecast data with high-resolution bathymetry to allow mariners to navigate in tight spaces and rapidly changing local conditions. The study will develop a port prioritization tool based on the amount of cargo entering and exiting the port, the number of accidents in the port, and the navigation challenges faced by the port. The study will also determine cost benefit metrics for implementing Precision Navigation. This tool will be applied to the ports of New York/New Jersey and the Lower Mississippi where NOAA is currently implementing Precision Navigation projects. The study results will provide further guidance to NOAA regarding which ports will benefit most from Precision Navigation and how these tools can best be used for future efforts.

Unraveling the story of salmon in the Pacific and Atlantic

Salmon support important commercial, recreational, Tribal, and subsistence fisheries, but several species are at risk. The North Pacific Anadromous Fish Commission and North Atlantic Salmon Conservation Organization declared 2019 as the International Year of the Salmon (IYS) to provide a framework for international outreach and research for salmon conservation, and NOAA is a participant of IYS. NOAA Fisheries researchers study Atlantic and Pacific salmon in different life stages from freshwater rivers to the open ocean to better understand what determines whether they live or die.

A hatchery smolt (top) captured in the Penobscot River Estuary that was likely injured during migration and will not survive in the ocean versus a wild smolt (bottom) captured with no injuries. Photo credit: NOAA NMFS/Northeast Fisheries Science Center

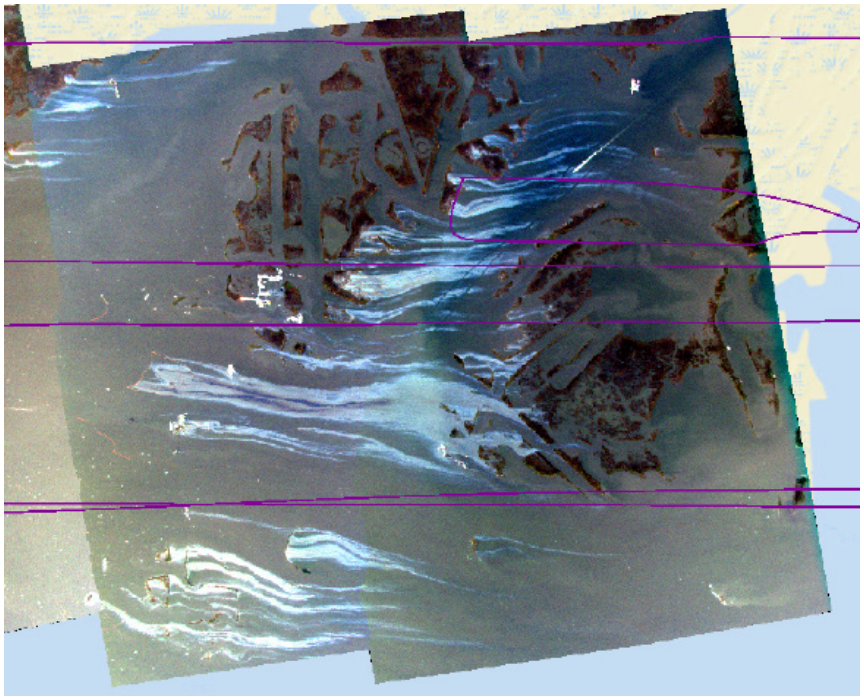
- Another project completed during IYS was in the Atlantic, where NOAA Fisheries researchers used a number of studies on juvenile salmon (smolt) behavior to model survival of hatchery-reared Atlantic salmon released at different locations along a river. The researchers found that smolts released into lower-river stocking sites reached the ocean in higher numbers than those released elsewhere because they encountered fewer dams and had shorter migration. These results highlight the challenge to conserve this species, which migrates from freshwater rivers - often with dams - to the ocean. This information can be used by state and Federal managers to better inform future salmon stocking strategies and work with the hydroelectric industry to minimize the impact of dams.
- Along the West Coast, an international team of biologists went into some of the roughest waters in the North Pacific Ocean in late winter to investigate the "black box" role of the open ocean in the Pacific salmons' life cycles. Twenty one scientists from five Pacific Rim countries, including NOAA Fisheries researchers, spent a month in the Gulf of Alaska catching, measuring, and sampling salmon, and brought home thousands of samples for a wide range of chemical and biological analyses over the coming months. As the first expedition in decades to study salmon in the high seas, the research provided the most comprehensive study of the entire ecosystem that salmon belong to.

Salmon caught on the high seas. Photo credit: NOAA NMFS

New tools to track oil spills, improve response

New technology is helping improve our ability to characterize oil in the environment, both in the immediate aftermath of a spill to provide scientific support for response, and for longer term characterization in support of natural resource damage assessments.

- NOAA, in close partnership with the U.S. Coast Guard, the Bureau of Safety and Environmental Enforcement, U.S. Environmental Protection Agency, academia, and multiple private research entities, is engaged in multiple airborne and space-based projects involving a variety of platforms (e.g., unmanned aerial systems [UASs], fixed wing platform in coordination with satellite) that are outfitted with oil-calibrated sensor packages to detect and characterize oil in the environment. Additionally, NOAA is actively developing and testing multiple autonomous underwater vehicles (AUVs) and remotely operated vehicle (ROV) systems to conduct three-dimensional mapping of oil and gas in the water column. These vehicles include larger ones that can travel over long ranges as well as smaller, portable, commercial-off-the-shelf vehicles.



Oil identification and mapping during the response to the 2018 Lake Washington, Louisiana pipeline release. Data were collected from a fixed wing platform (airplane) using an RGB (red green blue) sensor calibrated for oil detection. This image was immediately developed into an oil thickness classification map during post-processing and used to guide on-water assets during the emergency response. Photo credit: Ocean Imaging

- NOAA NESDIS transitioned a new tool into operations that helps track in near real time oil spill information from vessels underway, moored, and involved in accidents; oil platform releases from accidents and damage due to hurricanes; natural seeps; and spills from land-based facilities which make their way to the water. The tool, called the automated Synthetic Aperture Radar (SAR) Oil Spill Mapping product will help improve oil spill response, protect public safety, and protect natural resources that are crucial to a strong Blue Economy, clean water, and sustainable fisheries.

Saildrones help monitor fisheries and changing ocean conditions

NOAA uses a range of unmanned surface vehicles (USVs) as platforms and systems to collect environmental data. The new technologies are helping expand research that improves our understanding of weather, climate phenomena, and environmental processes.

- NOAA Fisheries used four Saildrone USVs to conduct coast-wide fisheries acoustic surveys and compare the results to those collected by NOAA Ship *Bell M. Shimada* on the same transects. The data comparisons are used to evaluate the data obtained with new tools. Stock biomass data from fisheries acoustic surveys are used to support fish stock assessments and inform management decisions. By using USVs, NOAA will be able to supplement shipboard surveys and improve our understanding of the ecosystem and fish stocks that NOAA manages.
- In August 2019, an unmanned Saildrone completed the first autonomous circumnavigation of Antarctica. The Saildrone carried an instrument developed by NOAA Research that collected oceanic and atmospheric carbon dioxide measurements. Despite hostile sea conditions, the USV completed the 13,670 mile journey, and the data it collected will allow scientists to better understand carbon dioxide processes in the Southern Ocean.

A saildrone maneuvering by wind. Note the solar panels that are used to power the onboard instruments. Photo credit: Saildrone, Inc.

Sustainable Use and Stewardship of Ocean and Coastal Resources

Four-month coral bleaching heat stress outlook

At least 500 million people rely on coral reefs for food, coastal protection, and their livelihoods. In providing coral reef awareness and actionable information, NOAA NESDIS offers the Coral Bleaching Heat Stress Outlook among the various products and services designed to monitor our nation's coral reefs. This Outlook blends several satellite data products for a more comprehensive regional alert for coral bleaching and helps coral reef managers better understand the onset of light/temperature stress, its buildup, and the eventual resultant coral bleaching and associated mortality. NOAA data scientists found that the most recent Four-Month Coral Bleaching Heat Stress Outlook, by testing previous models, known as hindcasting, enhanced NOAA's ability to predict the likelihood of coral bleaching heat stress up to four months in the future (the typical length of a bleaching season). This edition provides more accurate and reliable heat stress predictions than prior versions. Today, thanks to NOAA's work, local coral reef communities can work with decision makers and elected officials to improve coral reef management and regulation in a warming climate. Coral reefs are estimated to provide over $9.8 trillion annually based on their values from recreation, fish habitat, coastal protection, and cultural value.

Bleached coral at Jarvis Island in the Pacific Remote Islands. Photo credit: NOAA

Sea Grant teams up with citizen scientists to improve coastal preparedness

A robust partnership led by Alaska Sea Grant and including the University of Alaska Anchorage and the state Division of Geological and Geophysical Surveys, is working with citizen scientists, including students, in Alaskan communities to collect information on shoreline erosion, storm surge, and wave conditions. The goal of the project is to use this information from monthly surveys in the NOAA NWS storm surge forecasting model to improve forecasts of storm surge and wave conditions. Alaska Sea Grant researchers collaborated with citizen scientists to estimate shoreline vulnerability to coastal hazards and trained citizen scientists to monitor shoreline erosion at six locations monthly. For example, in Utqiagvik (formerly known as Barrow), the northernmost city in the U.S., Sea Grant researchers trained citizen scientists to monitor shoreline for erosion and flooding. Monitoring will take place over several years and the resulting data will be used to strengthen Utqiagvik's erosion forecasting system so managers will know where the greatest threats exist during any given storm.

Understanding decisions to participate in oyster aquaculture in Maryland

NOAA-funded work through Maryland Sea Grant and the University of Maryland investigated Maryland's wild oyster harvesters (watermen) and their decisions related to oyster aquaculture. Preliminary findings indicate that watermen are increasingly involved in aquaculture while remaining active in the public oyster fishery. For many, aquaculture provides income that can be drawn upon if needed. Still, challenges remain. There are concerns over initial aquaculture start-up costs and applying for loans, changing harvest practices, and competition for the best available Bay locations for oyster production. These findings helped inform state managers and Maryland Sea Grant extension agents regarding potential barriers to entry for watermen.

Environmental assessment of Bristol Bay, Alaska

NOAA NOS, in collaboration with the U.S. Fish and Wildlife Service, the University of Alaska Fairbanks, and the State of Alaska, completed an environmental characterization study of the northeastern reaches of Bristol Bay, Alaska. Bristol Bay has one of the most productive and economically important salmon fisheries in the world. The juvenile salmon live in the estuary for a time after they migrate downstream, yet the bay has never been systematically surveyed for ecological conditions that could threaten the salmon. The researchers found that levels of toxic chemicals, e.g., dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), metals and metalloids, except arsenic, were low relative to sediment quality guidelines. The scientists found no trace of a 2011 PCB spill. The study region was virtually absent of significant sediment toxicity, except for selected locations in the vicinity of fish processing plant waste streams where toxic levels of ammonia were present. Resident fish were generally healthy and had few contaminants. Bottom sediment dwelling animal communities, such as worms, shrimp, and sea stars, were abundant. The estuary is pristine and uncontaminated, but development projects in the watershed need to be carefully designed to avoid harming this valuable and vulnerable fishery resource.

An oyster farmer tends to his lines. Photo credit: Mississippi-Alabama Sea Grant Consortium

The volcano steam vent on Mt. Redoubt. Photo credit: Ian Hartwell

Science Highlights

A Robust and Effective Research and Development Enterprise

Earth observations, models, and data form a foundation for NOAA science, and integrating social sciences into NOAA's foundational processes increases the accessibility, comprehension, and utility of NOAA's R&D.

In 2019, NOAA's scientific accomplishments for building a robust and effective research and development enterprise included the following:

- ProbSevere: Tool to improve severe weather warnings
- U.S. Argo Program - Global ocean observations for understanding and prediction of climate variability
- Science clears the air in dust storm response
- Robotic ocean gliders collect data to improve hurricane forecasts
- Using a new product to better understand water vapor
- NOAA satellite detects real-time volcano ash
- NOAA PolarWatch
- Improving national ocean modeling to meet interagency needs
- Machine learning is improving the identification of harmful algal blooms
- Earth Prediction Innovation Center supports community modeling
- Integrating satellite information on lightning likely to improve hurricane forecasting
- Improved measuring of the Sun's energy output
- Improving oil spill modeling and response
- Using big data to understand data-poor fisheries
- Launch of Marine Biodiversity Observing Network Seascapes products on CoastWatch

ProbSevere: Tool to improve severe weather warnings

Current satellite, radar, lightning detection, and Numerical Weather Prediction data sets contain a wealth of information for identifying severe weather threats such as large hail, damaging wind, and tornadoes. The primary challenge is extracting the pertinent information from an enormous volume of data in a timely manner. The ProbSevere (short for "Probability of Severe") project, led by NOAA NESDIS, is utilizing machine learning to rapidly distill large volumes of environmental data into actionable information in support of NOAA NWS severe weather warning operations. Feedback from the numerous NOAA NWS forecasters that evaluated ProbSevere in NOAA testbeds and Weather Forecast Offices, including the 2019 Hazardous Weather Testbed, confirms ProbSevere often allows them to extend the lead time of severe thunderstorm and tornado warnings, thereby giving the public more time to seek shelter and prepare for severe weather impacts. The ProbSevere tool is planned to be transitioned to NOAA NWS operations in 2020 and current research is aimed at further enhancing the capabilities through the use of artificial intelligence.

NWS forecasters use ProbSevere to assess the potential for severe weather during the NOAA Hazardous Weather Testbed. Photo credit: Justin Sieglaff, University of Wisconsin-Cooperative Institute for Meteorological Satellite Studies

U.S. Argo Program - Global ocean observations for understanding and prediction of climate variability

Argo floats collect high-quality temperature and salinity profiles from the upper two kilometers (1.2 miles) of the ocean, and the program exemplifies international collaboration on a scale rarely seen in the scientific community. The U.S. currently contributes roughly 1,800 floats to the Argo program — approximately half of the global array. As of the end of 2019, Argo has 3,883 floats worldwide and achieved a major milestone delivering its two millionth ocean measurement. NOAA Research is committing resources towards the Argo biogeochemical mission (whose sensors measure pH, nitrate, backscatter, fluorescence, and oxygen in addition to temperature and salinity), which will increase capacity across NOAA and within the U.S. to utilize this new sensor technology to better monitor and eventually predict ocean and marine ecosystem health. The Argo vision for a global full-depth and multidisciplinary array will enable a new range of forecasting capabilities, fundamental ocean research, climate assessments, and Blue Economy and ocean health benefits.

Science clears the air in dust storm response

NOAA Research works cooperatively with regional decision-makers to produce climate research that reduces vulnerabilities — including economic damages — that Americans face every year due to climate and extreme weather impacts. One of NOAA's 11 Regional Integrated Sciences and Assessments (RISA) teams, the Climate Assessment for the Southwest (CLIMAS) is composed of experts from a variety of social, physical, and natural sciences who work with planning officials, resource managers, businesses, and other partners across the Southwest to develop sustainable answers to regional climate challenges. In 2019, CLIMAS continued to build on existing partnerships with state officials in New Mexico and Arizona to address the impacts of extreme drought and dust storms on transportation systems. CLIMAS researchers provided the scientific evidence to support the development of a convective dust storm warning product now in operation at the El Paso, Texas and Phoenix, Arizona Weather Forecast Offices. As Interstate 10 is projected to carry up to 25,000 commercial trucks per day by 2040, the warning product is a critical tool to save lives and reduce the economic impact of crashes and road closures to the trucking industry.

Top left - trucking industry partner; bottom left - Dave Dubois, New Mexico State Climatologist and CLIMAS researcher; top and bottom right: DOT surveyors. Photo credit: NOAA Climate Program Office Video 2018, "NOAA RISA's CLIMAS Team: Science Clears the Air in Dust Storm Response"

View from vehicle on I-10 with newly installed NM DOT warning signs. Photo credit: NOAA Climate Program Office Video 2018, "NOAA RISA's CLIMAS Team: Science Clears the Air in Dust Storm Response"

> *"Through this [interaction with CLIMAS RISA] we were able to quickly build up a level of knowledge about dangers in the area and the frequency of dust storms."*
>
> *- Trent Botkin, New Mexico Department of Transportation*

Robotic ocean gliders collect data to improve hurricane forecasts

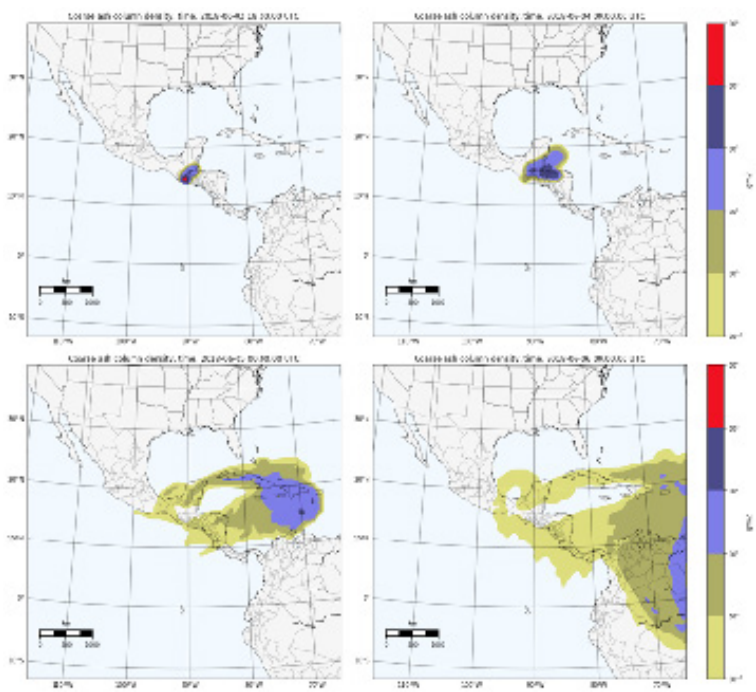
The U.S. is leading a multilateral effort to improve regional capacity for hurricane forecasts in the Caribbean Sea and tropical North Atlantic Ocean. NOAA is partnering with U.S. universities and academic and regional governmental institutions in Puerto Rico, the Dominican Republic, the U.S. Virgin Islands, and the Bahamas to create a sustained network of underwater gliders. In 2019, NOAA scientists launched two underwater gliders in the Caribbean Sea, two in the tropical North Atlantic Ocean, one off the Dominican Republic, one south of the U.S. Virgin Islands, and one east of the Bahamas. These robotic, unmanned gliders are equipped with sensors that measure ocean salinity and temperature as they move throughout the ocean at depths of up to a half mile below the surface. Because warmer waters can lead to stronger hurricanes, and salt content can affect sea surface temperature, scientists hope that the data these gliders bring back will improve the accuracy of hurricane forecast models.

Deployment of one Atlantic Oceanographic and Meteorological Laboratory glider in the Caribbean Sea with partners from the University of Puerto Rico and the Caribbean Regional Association for Coastal Ocean Observing (CARICOOS). Photo credit: NOAA

Using a new product to better understand water vapor

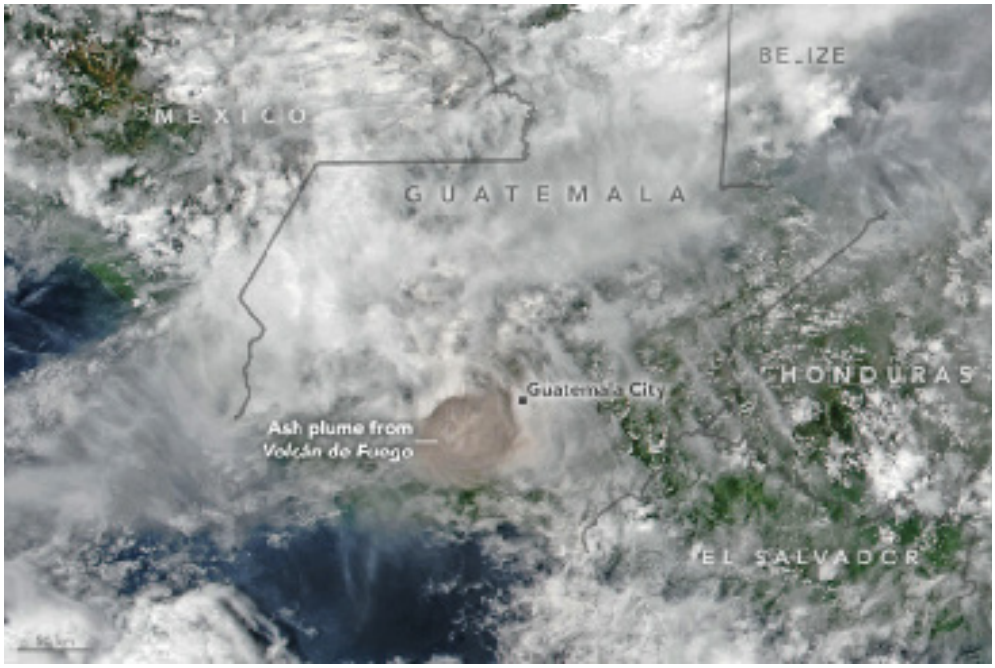
Water vapor drives many high-impact weather events, such as heavy precipitation and flooding. However, its vertical profile is poorly observed by land-based radiosondes and over ocean where measurements, except from satellites, are sparse or non-existent. The Cooperative Institute for Research in the Atmosphere (CIRA), funded by NOAA NESDIS, is creating an hourly Advected Layer Precipitable Water (ALPW) product which lets forecasters see atmospheric moisture features in four vertical layers. CIRA is currently distributing the product to NOAA National Centers (Water Prediction Center, National Hurricane Center) and 23 Weather Forecast Offices, and forecasters are being trained to use the product.

NOAA satellite detects real-time volcano ash



Using data from the Geostationary Operational Environmental Satellite-R Series (GOES-R), NOAA NESDIS created products that provide the location and heights of volcanic ash plumes. Using the information from these products, the researchers have developed an experimental model that automatically simulates the dispersion of volcanic plumes in near real-time. The experimental model could provide decision support information for air traffic route managers and reduces risk for people and infrastructure during volcanic eruption events. NOAA is using the model to evaluate the performance of the GOES-R data retrievals and create volcanic ash alerts on an experimental basis.

The Fuego Eruption in Guatemala in June 2018 was a perfect example when satellite detection of the volcanic ash was partly hampered and masked by clouds. Nevertheless, ash plumes were detected from the Visible Infrared Imaging Radiometer Suite (VIIRS) and GOES-R. The figures show the Fuego ash plume as seen from VIIRS at 1900 UTC of June 3, 2018, and a false color imagery of GOES-R thermal bands indicating the Fuego Volcanic Thermal Anomaly. The last Fuego figure shows the erupted Fuego volcanic ash cloud simulated by a model for the first 3 days from June 3rd, 18:00 UTC until June 6th, 00:00 UTC. The model-simulated volcanic ash dispersion helped to track the evolution of the ash plume, and thus to evaluate the GOES-R Advanced Baseline Imager (ABI) Volcanic Ash Detection and Height baseline product. Image credit: False color images provided by Mike Pavolonis, NOAA/Cooperative Institute for Meteorological Satellite Studies/Volcanic Cloud Monitoring

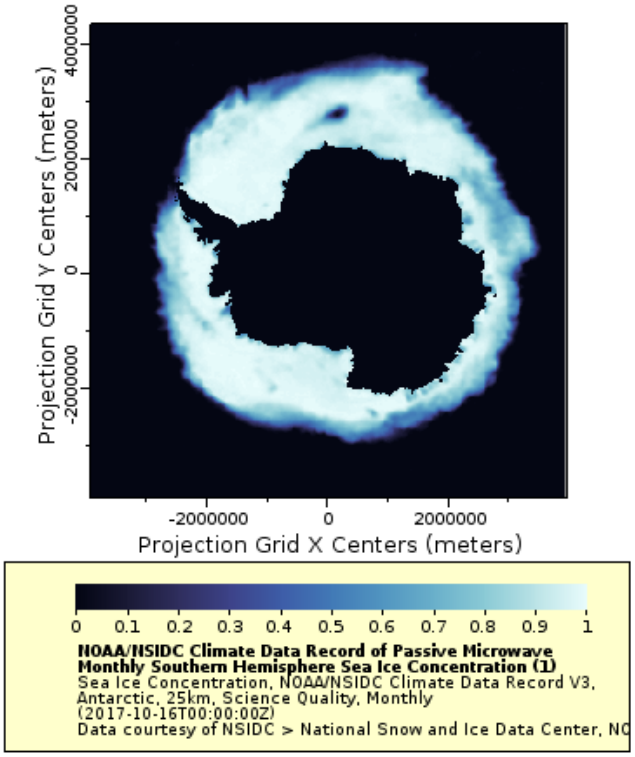


NOAA PolarWatch

NOAA PolarWatch is the newest satellite data distribution portal of NOAA NESDIS's CoastWatch program. The portal offers a single location for Federal agencies, research groups, and private industry to obtain recent and historical satellite observations of Arctic and Antarctic waters, including measurements of sea ice cover, ocean temperature, and winds. PolarWatch's data and services help enhance public safety and the Blue Economy, and support Federal agencies (e.g., Homeland Security, Coast Guard, etc.) and private industry for safety at sea, navigation, fishing, transportation, tourism, and recreation. PolarWatch also provides support and training to encourage broad use of polar satellite data across a diverse stakeholder community.

"Being able to post U.S. NIC [National Ice Center] operational snow and ice products to the PolarWatch site allows us to meet customer requirements to distribute to as wide of a user community as possible. The targeted audience of PolarWatch is a new set of customers outside the numerical weather prediction community who we currently target."

- John Woods, NOAA Snow and Ice Products Area Lead (PAL), U.S. National Ice Center

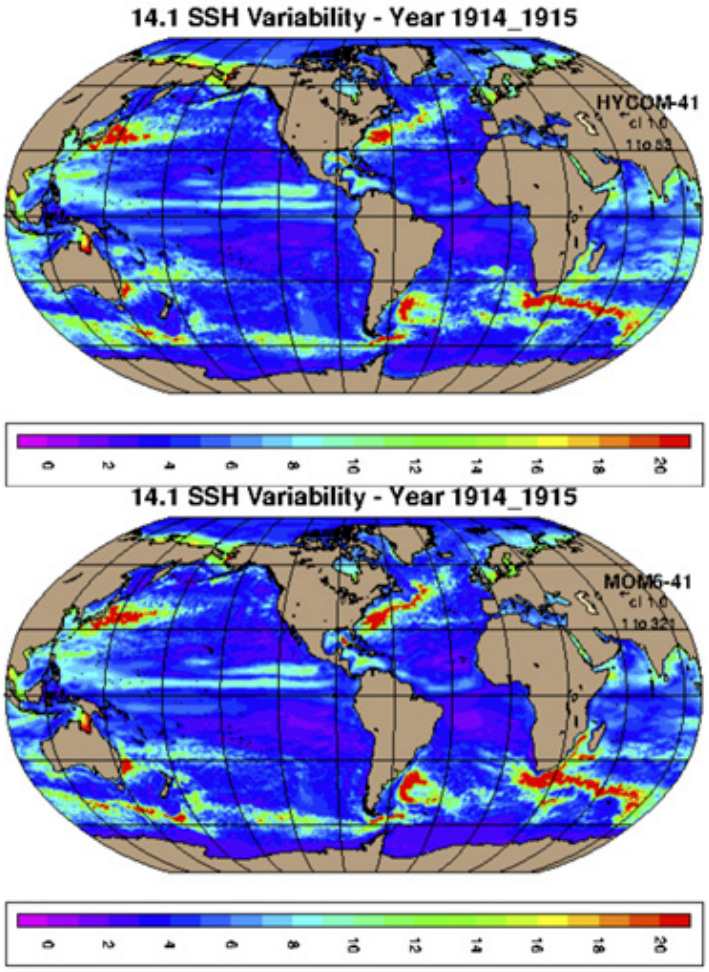


A monthly composite image of Antarctic Sea Ice Concentration showing a polynya, a large ice-free area surrounded by sea ice, in the western Lazarev Sea (for the period September 17-October 16, 2017). Image credit: NOAA.

"The collaboration with PolarWatch to serve the SOCCOM [Southern Ocean Carbon and Climate Observations and Modeling] data on PolarWatch will open new avenues for data access and analysis and new windows on Southern Ocean biogeochemistry. This will be a real benefit to modelers and others who want to access and explore this unique data set."

- Ken Johnson, Senior Scientist at the Monterey Bay Aquarium Research Institute (MBARI) and the Co-Chair, U.S. Biogeochemical-Argo Subcommittee

Improving national ocean modeling to meet interagency needs



A new global eddy-resolving (1/12° resolution) configuration of the Modular Ocean Model (MOM6), compares favorably with operational versions of HYCOM. Photo credit: Robert Hallberg, NOAA/OAR/Geophysical Fluid Dynamics Laboratory

NOAA participates in the National Earth System Prediction Capability (ESPC) interagency partnership, which strives for improved earth system prediction for decision support on timescales from hours to 30 years. Advanced global ocean modeling valid across scales is key to this capability. Presently many Federal and academic partners use either the Modular Ocean Model (MOM), with its emphasis on longer time scales, or the Hybrid Coordinate Ocean Model (HYCOM) with its emphasis on high resolutions. Researchers have tested MOM6 at the high horizontal and vertical resolutions of HYCOM, implemented a Gulf of Mexico nest to test and support coastal modeling needs, and improved how the ocean model connects to the sea ice model for more efficient calculation. The researchers' ongoing work continues to implement tide calculations and improve model initialization.

Machine learning is improving the identification of harmful algal blooms

A NOAA NOS collaborator, Axiom Data Science, is advancing the use of machine learning for identification of algal species from high resolution images collected by automated submersible microscopes, such as Imaging Flow Cytobot (IFCB), and other harmful algal bloom (HAB) sensors. Axiom, in collaboration with the University of California Santa Cruz (UCSC) and Monterey Bay Aquarium Research Institute (MBARI), has developed a full working prototype data stream for identifying potentially toxic species in real-time using image analysis and machine learning tools. This will improve the ability of resource managers to respond to potential events more quickly.

Earth Prediction Innovation Center supports community modeling

NOAA is developing a community modeling framework for its next-generation earth system modeling capability, referred to as the Unified Forecast System (UFS), to transition research to operations that will improve weather forecasting. Through the support of the Earth Prediction Innovation Center (EPIC), the UFS connects model applications and components together to make a coupled earth system model that is based on the Finite Volume Cubed (FV3) dynamic core and sophisticated computer algorithms that solve large, complex physics equations; it spans timescales from short term weather to two to four week forecasts. To support this community development, EPIC committed resources to provide open repositories with proper documentation, code managers for all of the model components, and continuous integration teams for testing the applications as the individual components are upgraded. Over the coming months, the UFS applications and components are transitioning to GitHub, a web-based open source software development platform.

By creating a community modeling framework for the UFS, NOAA will better be able to transition research to operations for improved modeling and forecasting of high impact weather events. EPIC serves to accelerate advances to the UFS by creating a true community earth systems model that is accessible to the public and utilizes innovative strategies to host, manage, and enable the development and maintenance of the model.

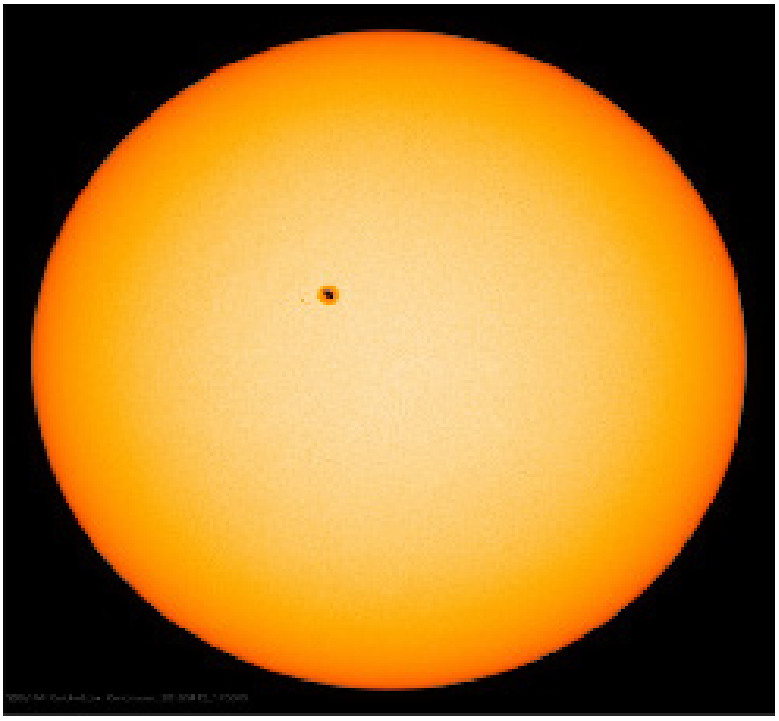
EPIC Community Workshop. Photo credit: Chantel Bivins

Integrating satellite information on lightning likely to improve hurricane forecasting

NOAA NESDIS researchers are integrating high resolution satellite data on lightning taken by the Geostationary Lightning Mapper (GLM) into hurricane forecasting, with the potential to improve hurricane forecasts. The ability of the GLM to produce high resolution data from over open oceans should be particularly helpful to predicting rapid intensification of tropical cyclones. Researchers have also been using artificial intelligence (AI) for GLM lightning forecast. The GLM forecast product for hurricanes will be developed and evaluated in collaboration with NOAA NWS.

Improved measuring of the Sun's energy output

The Sun's power per unit area, or irradiance, is our planet's most important source of external energy and drives the terrestrial and atmospheric interactions that define our climate. Accurate data on the total solar irradiance (TSI) and solar spectral irradiance (SSI) are essential for Earth atmospheric and climatic studies over broad timescales (minutes to centuries and longer). To meet the needs of the research community, NOAA completed the transition into operations of the U.S. Naval Research Laboratory's (NRL) solar variability models that specify the Total Solar Irradiance and Solar Spectral Irradiance Climate Data Records (CDR). The NRL models have been used in many climate studies and in past assessments of Earth's climate by the Intergovernmental Panel on Climate Change (IPCC). The NRL models are derived from satellite irradiance observations from the Solar Radiation and Climate Experiment (SORCE). Key new observational datasets from the Total and Spectral Solar Irradiance Sensor (TSIS-1) mission that are being made since 2018 have sufficient repeatability and accuracy to provide direct and tangible benefits for solar irradiance model improvements and for the Solar Irradiance CDR. A new version of the TSI and SSI CDR is in development and will incorporate an improved baseline absolute SSI irradiance scale and an improved understanding of spectral irradiance variability based on TSIS observations.



The Sun is currently in a minimum solar activity phase. The first significant sunspot passage occurred on April 1-21, 2019 and resulted in a 0.03 percent decrease in TSI as observed by the TSIS Total Irradiance Monitor (TIM) instrument. Improvements in the Solar Irradiance CDR, particularly in the solar spectrum, will be obtained from the superior precision of the TSIS SIM instruments over other SSI measurements, such as shown here by the Solar Radiation and Climate Experiment (SORCE) Spectral Irradiance Monitor instrument. Image credit: Helioseismic and Magnetic Imager science data courtesy of NASA Solar Dynamics Observatory

Improving oil spill modeling and response

Being able to predict where oil or other pollutants will travel once they've been spilled into a waterway is important for oil spill response crews. This year, NOAA improved its suite of modeling tools, called the General NOAA Operational Modeling Environment (GNOME) to provide critical, time-sensitive information about how spilled oil will move throughout the environment. This information supports the more than 175 yearly NOAA oil response operations by helping decision-makers determine what areas of the spill are the heaviest and where they need to send their limited response assets first. In 2019, NOAA enhanced the visualization of model results in WebGNOME, GNOME's online component. The team is working on multiple oil spill modeling-related projects with the Arctic Domain Awareness Center to enhance our ability to model oil in ice environments. It is also working with NOAA laboratories and external partners on methods to enhance recovery of oil-affected marshes. These projects result in a more efficient clean-up operation, which translates to fewer resource injuries with faster recovery times.

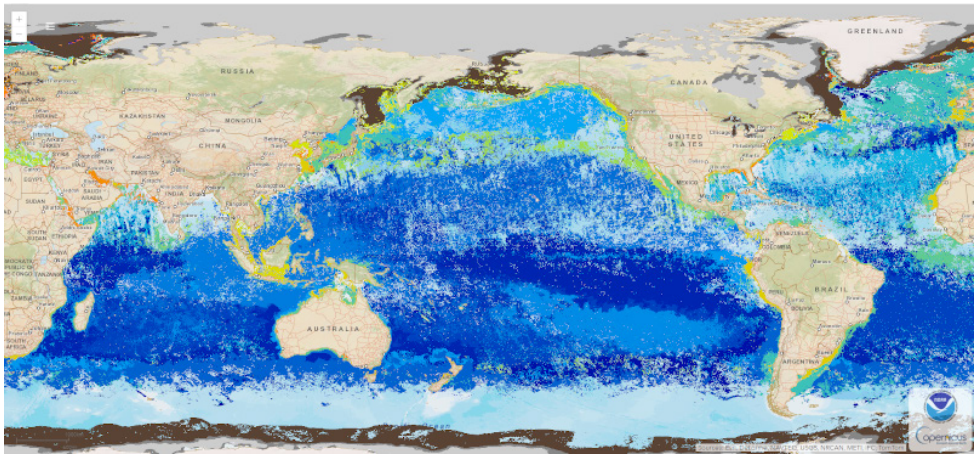
NOAA salt marsh mesocosms in Charleston, SC used for testing recovery of oiled marshes. Image Credit: NOAA

Using big data to understand data-poor fisheries

NOAA Fisheries is developing novel ways to use big data gathered by Vessel Monitoring Systems (VMS) and Automatic Information Systems (AIS) that are deployed on fishing vessels in many fisheries in the U.S. and around the world to improve fishery and ecosystem management. Recent research conducted by NOAA Fisheries and academic partners have accurately used VMS data to estimate where and when fishing occurs, knowledge that is important in many fishery stock assessments and in improving the economic performance of fisheries. Current collaborations are integrating VMS data (e.g., vessel identification data, position, and time) with environmental satellite data, which will improve efficiency and provide consistent data that will allow researchers to better understand the decisions that fishermen make about when and where to fish. This research is increasingly important for understanding the impact of climate change on fisheries management, economics, and fishing communities as fisheries and species distributions change, especially when fish stocks may span national borders. Beyond improving our understanding of domestic fisheries, AIS data can provide information on many foreign fishing vessels fishing near the boundaries of the U.S. Exclusive Economic Zone and on the high seas, assisting enforcement efforts aimed at illegal, unreported, and unregulated fishing. The combination of this improved understanding of fishing behavior from VMS and AIS data with observer and electronic monitoring programs and tools, such as dynamic ocean management and bycatch reduction incentives, provides a cost-effective way to sustainably protect and utilize the Nation's marine resources.

Launch of Marine Biodiversity Observing Network Seascapes products on CoastWatch

United States and global Marine Biodiversity Observing Network (MBON) partnered with U.S. Integrated Ocean Observing System (IOOS®), NOAA Research, and NOAA NESDIS to develop and routinely generate "seascapes" products and to make them available on NOAA's CoastWatch. Derived from dynamic fields of satellite and modeled data, seascapes are a biogeographical framework to describe changing ocean habitats for observing marine biodiversity and other applications like coastal and fishery management. Seascapes provide information about the quality and extent of different oceanographic habitats or features, and they can be used to assess and predict different species within the habitats, like plankton or fish populations. Current CoastWatch seascapes products include monthly and eight day time steps with a spatial resolution of 1/20th of a degree (~ five km). High resolution (one km) case studies are planned on a case by case basis as through cooperation with the U.S. and global MBON partners. MBON is a growing national and global initiative composed of regional networks of scientists, resource managers, and end-users working to integrate data from existing long-term programs to improve our understanding of changes and connections between marine biodiversity and ecosystem functions. The U.S. MBON projects are integrating independent historical and current biology and ecosystem surveys with new observations, and expanding application of remote sensing methods, novel molecular (eDNA) technologies, traditional environmental research tools, and coordinated experiments.



The NOAA CoastWatch website. Image credit: NOAA

"Satellite seascape maps allow us to monitor shifts in surface habitat conditions and the biota carried within them, including harmful algal blooms, fisheries populations and migratory species." – Enrique Montes, College of Marine Science, University of South Florida

Bibliometrics

This chapter represents a rigorous assessment of NOAA's scholarly research output between 2011 and 2018. Through analysis of publications authored during that time period, NOAA's core research areas were identified and used to establish a robust scholarly performance metric to demonstrate NOAA's productivity and impact within these research areas. As a benchmarking exercise, these metrics were then compared with those of other Federal agencies conducting research in these disciplines.

The research areas listed below represent the bulk of NOAA's scholarly output between 2011 and 2018, with approximately 82 percent of all NOAA articles identified falling within one or more of these eight disciplines, all of which are strongly aligned with the agency's mission objectives.

1. Meteorology and Atmospheric Sciences
2. Environmental Sciences
3. Marine and Freshwater Biology
4. Oceanography
5. Ecology
6. Fisheries
7. Geosciences
8. Remote Sensing

For each research area, we then compared NOAA's productivity and impact metrics with those of the four other Federal agencies that were most productive in that research area.

List of comparison agency abbreviations:

NASA	National Aeronautics and Space Administration
DOE	Department of Energy
DOD	Department of Defense
DOI	Department of the Interior
EPA	Environmental Protection Agency
USDA	U.S. Department of Agriculture
SI	Smithsonian Institution

Bibliometrics

Methodology

Scholarly data and metrics for this report were obtained using InCites (Clarivate Analytics), a web-based platform that allows for the assessment of the research productivity and relative impact of research organizations based on peer-reviewed articles indexed in Web of Science.

For the purposes of this report, a "NOAA article" is defined as a peer-reviewed publication indexed in the Web of Science (WoS) Core Collection and identified by WoS indexers as having one or more authors who list their affiliation as National Oceanic and Atmospheric Administration. This report analyzes articles that fit this criteria and were published between 2011 and 2018 and indexed in the InCites dataset as of September 26, 2019. Articles that only acknowledge the receipt of financial, logistical or other support from NOAA or any NOAA office or program are not included in this report. Also not included in this analysis are book chapters, conference papers, technical reports, and other items including some journal articles which are not indexed by WoS. As such, the publication counts presented in this report can be assumed to be undercounts of the actual number of publication produced by NOAA. However, the reported counts can be considered a representative sample of NOAA's research output between 2011 and 2018. This report focuses on NOAA's eight core research areas, determined by using the WoS research schema, comprised of 252 research areas assigned to articles based on the journals in which they are published. Within each research area, productivity and impact was assessed based on the total number of published articles and the following citation metrics: i) Hirsch-Index or H-Index; ii) percent of documents which have received citations; iii) percent of documents in the top 10 percent of articles cited. For benchmarking purposes, productivity and impact data were collected for the four most productive Federal agencies aside from NOAA, within each core research area. The articles on which these data are based are identified using the same methodology used for identifying NOAA articles. Additional productivity and citation metrics have been included which illustrate NOAA's research output as a whole and provide context for the rest of the analysis. These metrics include total number of NOAA-authored peer-reviewed publications, total citations received, percent of articles cited, percent of articles in the top 10 percent by citation, and international collaborations and were obtained using InCites and WoS. The international collaborations map was created using the Science of Science Tool (Sci2) using the country or territory associated with author affiliations for coauthors of NOAA-articles for which that data were available.

The analysis in this report is distinct from that presented in the *Bibliometrics Analysis of Articles by NOAA-Affiliated and Funded Authors Published During Fiscal Year 2018* as the time period covered and dataset analyzed differ significantly. The analysis in that report is based on a curated bibliography of N OAA articles published between fiscal years 2012 and 2018 as identified by the staff in the NOAA Central Library. Any discrepancies in publication counts or indicators is due to this difference in methodology.

References:

NAS (2012). Best Practices in Assessment of Research and Development Organizations, The National Academies Press.

D. Hicks, P. Wouters, L. Waltman, S. de Rijke, I. Rafols. (2015). The Leiden Manifesto for Research Metrics, *Nature* (520) 429-431.

NOAA peer-reviewed articles 2011-2018

15,686
Total Publications

168
H-index

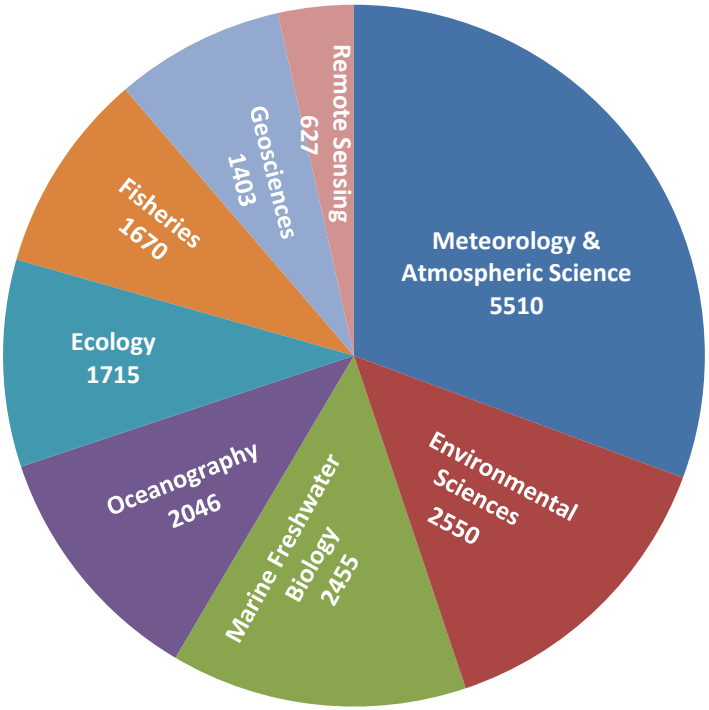
322,064
Sum of Times Cited

93%
% of Articles Cited

19.81%
of Articles in Top 10 Percent by Citation

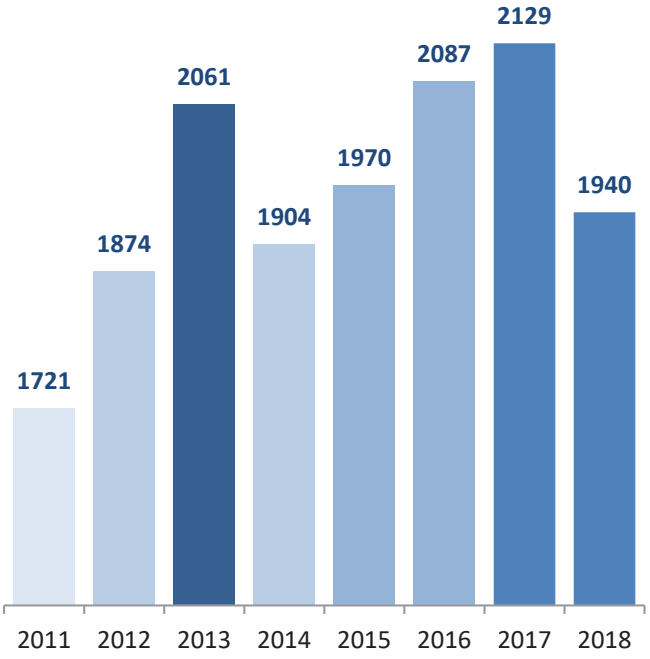
A "NOAA article" is defined as a peer-reviewed publication indexed in the Web of Science (WoS) Core Collection and identified by WoS indexers as having one or more authors who list their affiliation as National Oceanic and Atmospheric Administration. This report analyzes articles that fit these criteria and were published between 2011 and 2018 and indexed in the InCites dataset as of September 26, 2019. As an organization, NOAA has an H-index of 168 meaning that of the 15,686 articles published by NOAA authors in the period this report reflects, 168 have been cited at least 168 times.

Top Research Areas



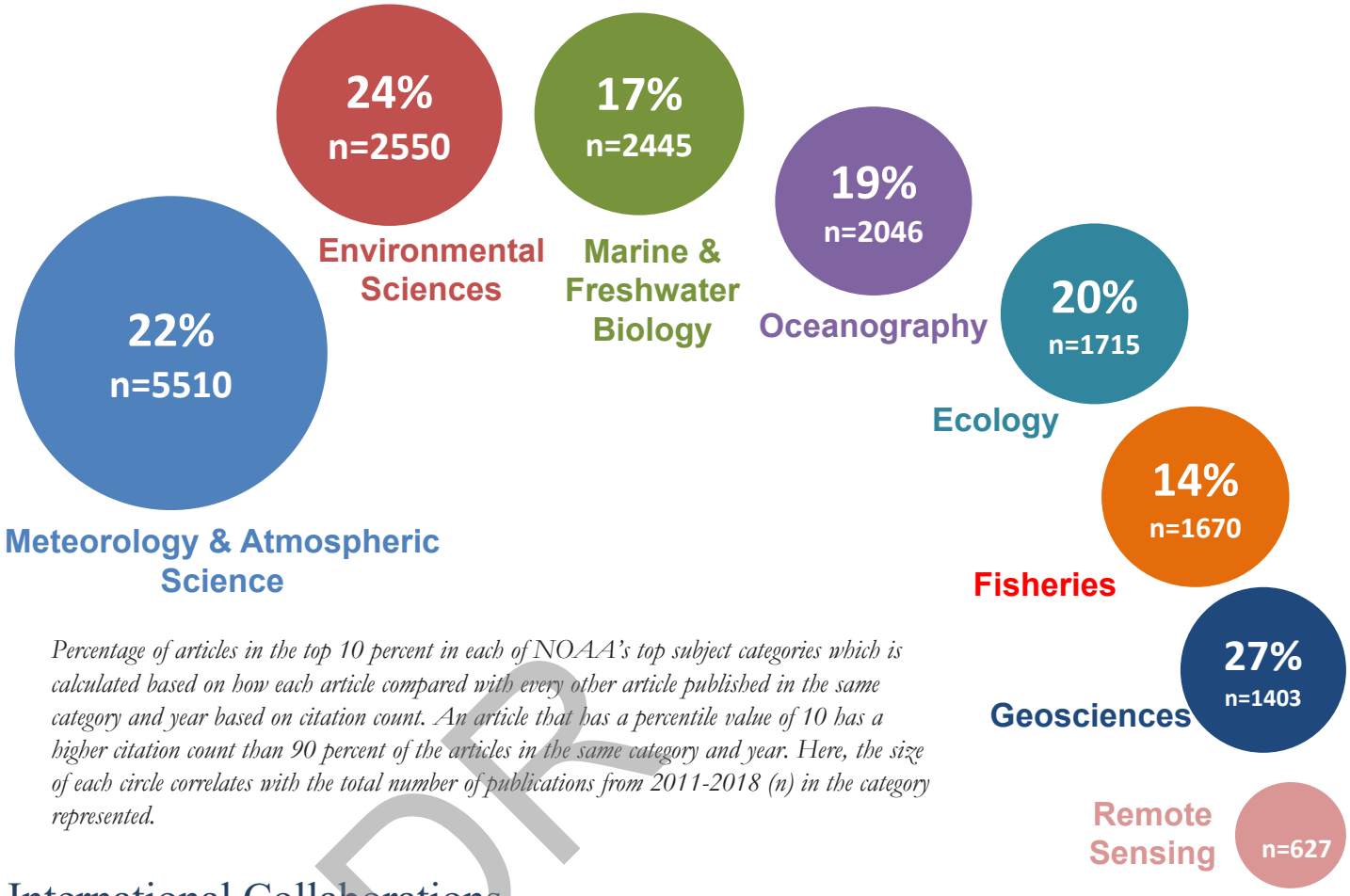
82 percent of NOAA articles fall within these eight subject categories. Subject categories are defined, and assigned to articles, by Web of Science based on the journal in which each article was published. A single article may be assigned to multiple subject categories.

Articles per year



Non-cumulative number of NOAA articles per year. On average NOAA authors have published 1,961 articles annually between 2011 and 2018.

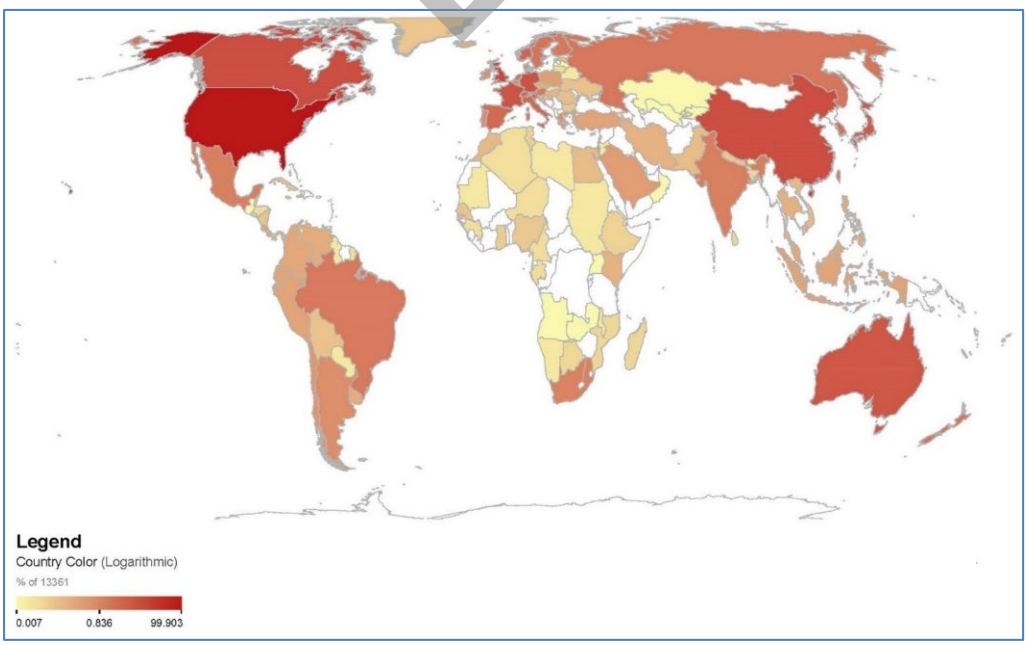
Percentage of Articles in Top 10 Percent by Citation



Percentage of articles in the top 10 percent in each of NOAA's top subject categories which is calculated based on how each article compared with every other article published in the same category and year based on citation count. An article that has a percentile value of 10 has a higher citation count than 90 percent of the articles in the same category and year. Here, the size of each circle correlates with the total number of publications from 2011-2018 (n) in the category represented.

DR

International Collaborations



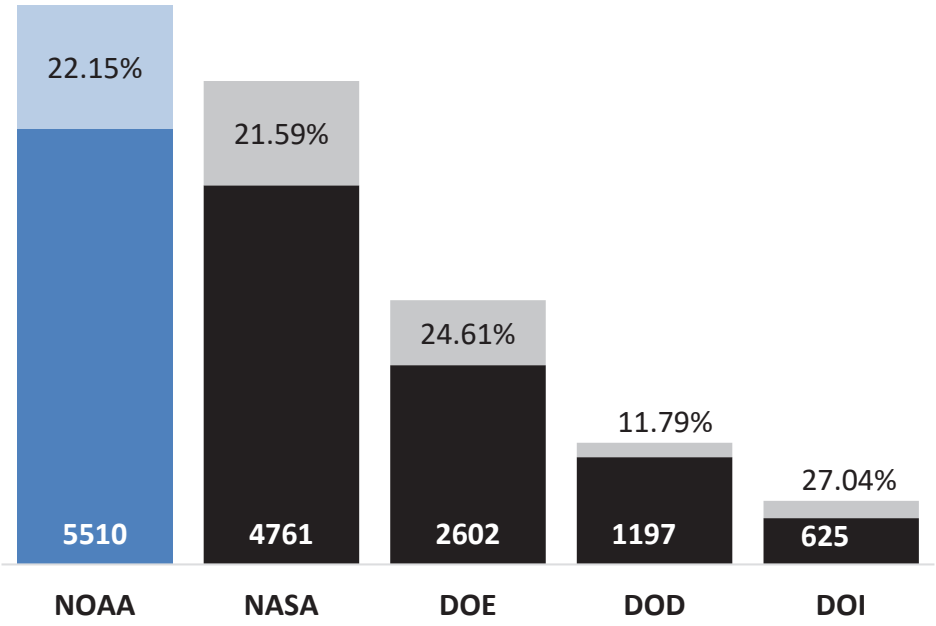
NOAA authors have collaborated with authors at **2,213** institutions in **184** countries and territories.

How to Read this Map

In this map each country is color coded in proportion to a numerical value which represents co-authorship on NOAA publications. Darker shades correlate with more articles coauthored with NOAA authors. Minimum and maximum data values are given in the legend.

Meteorology and Atmospheric Sciences

Total Number of Articles by Agency



Top Journals where NOAA Publishes

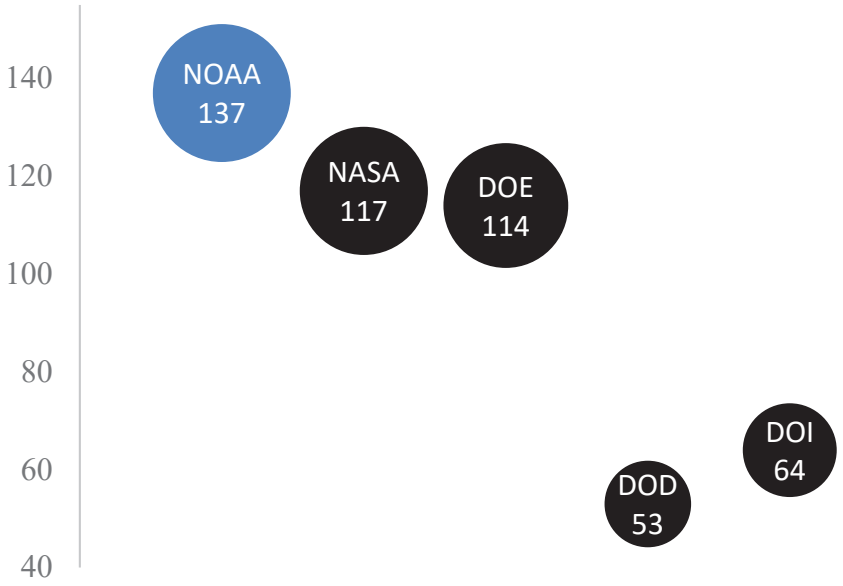
- *Journal of Climate*
- *Bulletin of the American Meteorological Society*
- *Atmospheric Chemistry and Physics*
- *Journal of Geophysical Research - Atmospheres*
- *Monthly Weather Review*

Between 2011 and 2018, NOAA published an average of approximately 688 articles per year in the field of meteorology and atmospheric sciences, resulting in a total of 5510 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in meteorology and atmospheric sciences.

Highly Cited NOAA Articles

- Stein, et al. 2015. NOAA'S HYSPLIT Atmospheric Transport And Dispersion Modeling System. *Bull Amer Meteor Soc.*
- Huang, et al. 2015. Extended Reconstructed Sea Surface Temperature Version 4 (ERSST.v4). Part I: Upgrades and Intercomparisons. *J Climate.*
- Karl, et al. 2015. Possible artifacts of data biases in the recent global surface warming hiatus. *Science.*

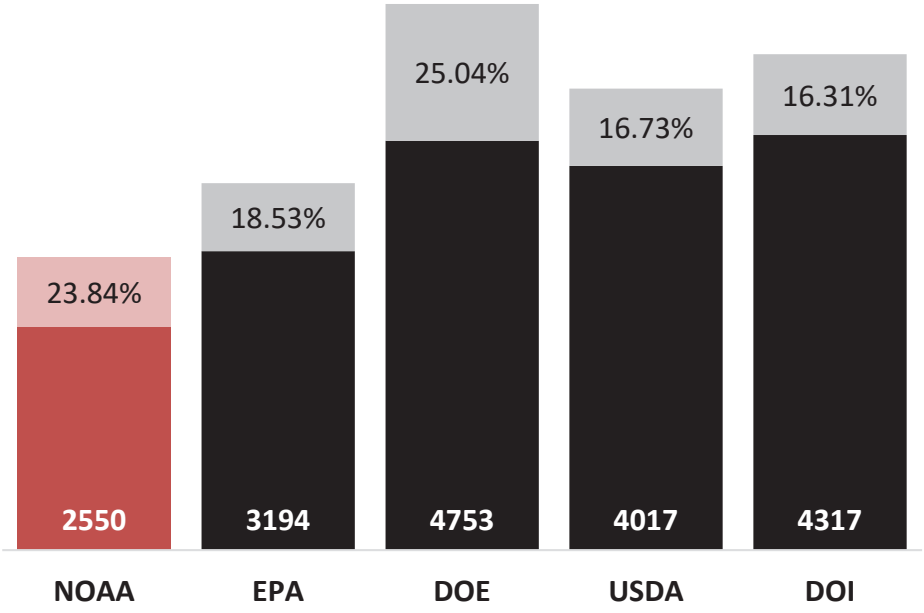
H-Index



Within the field of meteorology and atmospheric sciences, NOAA has an H-index of 137 - meaning that 137 of these articles have been cited in the peer-reviewed literature at least 137 times.

Environmental Sciences

Total Number of Articles by Agency



Top Journals where NOAA Publishes

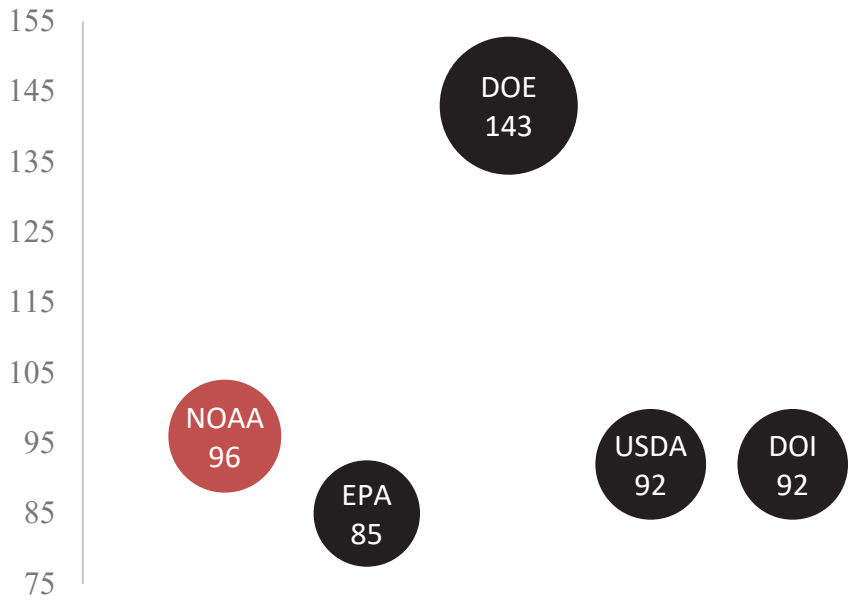
- *Atmospheric Chemistry and Physics*
- *Nature Climate Change*
- *Environmental Science & Technology*
- *Atmospheric Environment*
- *Remote Sensing of the Environment*

Between 2011 and 2018, NOAA published an average of approximately 319 articles per year in the field of environmental sciences, resulting in a total of 2550 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in environmental sciences.

Highly Cited NOAA Articles

- Xu, et al. 2015. Effects of anthropogenic emissions on aerosol formation from isoprene and monoterpenes in the southeastern United States. *PNAS*.
- Monks, et al. 2015. Tropospheric ozone and its precursors from the urban to the global scale from air quality to short-lived climate forcer. *Atmos Chem & Phys*.
- Cai, et al. 2015. ENSO and greenhouse warming. *Nature Climate Change*.

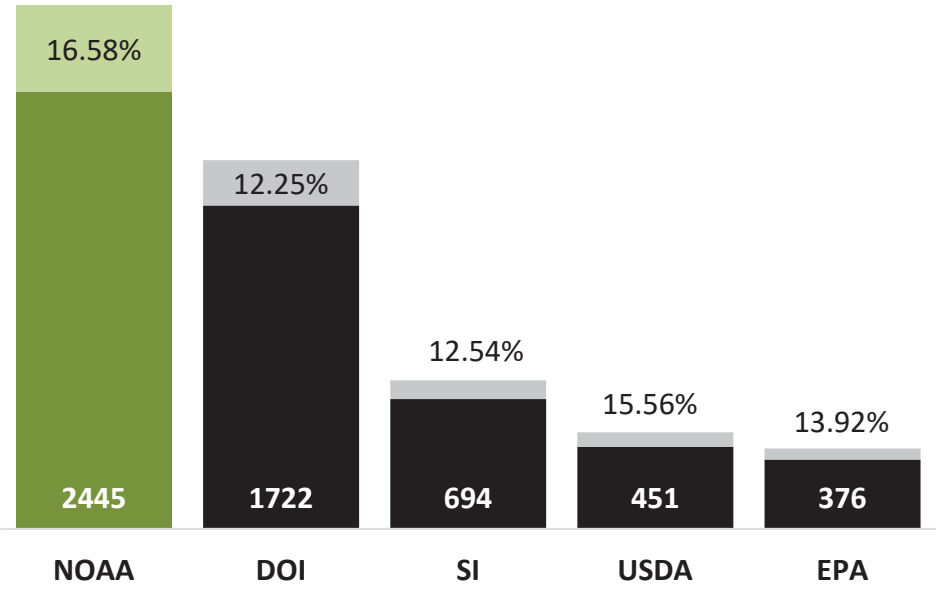
H-Index



Within the field of environmental sciences, NOAA has an H-index of 96 - meaning that 96 of these articles have been cited in the peer-reviewed literature at least 96 times.

Marine and Freshwater Biology

Total Number of Articles Per Agency



Top Journals where NOAA Publishes

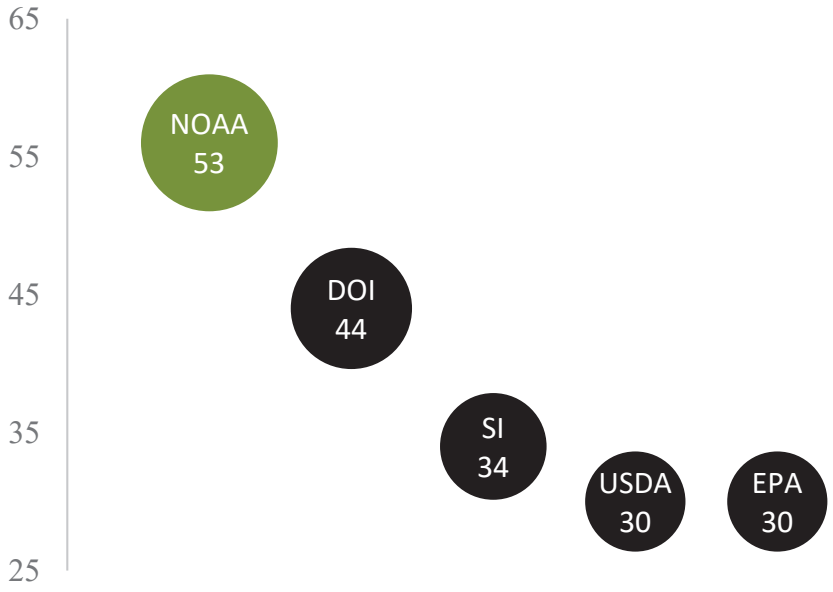
- *Marine Ecology Progress Series*
- *ICES Journal of Marine Science*
- *Canadian Journal of Fisheries & Aquatic Sciences*
- *Marine Pollution Bulletin*
- *Marine Mammal Science*

Between 2011 and 2018, NOAA published an average of approximately 306 articles per year in the field of marine & freshwater biology, resulting in a total of 2445 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in marine and freshwater biology.

Highly Cited NOAA Articles

- Wells, et al. 2015. Harmful algal blooms and climate change: Learning from the past and present to forecast the future. *Harmful Algae*.
- Heron, et al. 2016. Warming Trends and Bleaching Stress of the World's Coral Reefs 1985-2012. *Scientific Reports*.
- Williams, et al. 2015. Human, Oceanographic and Habitat Drivers of Central and Western Pacific Coral Reef Fish Assemblages. *PLOS One*.

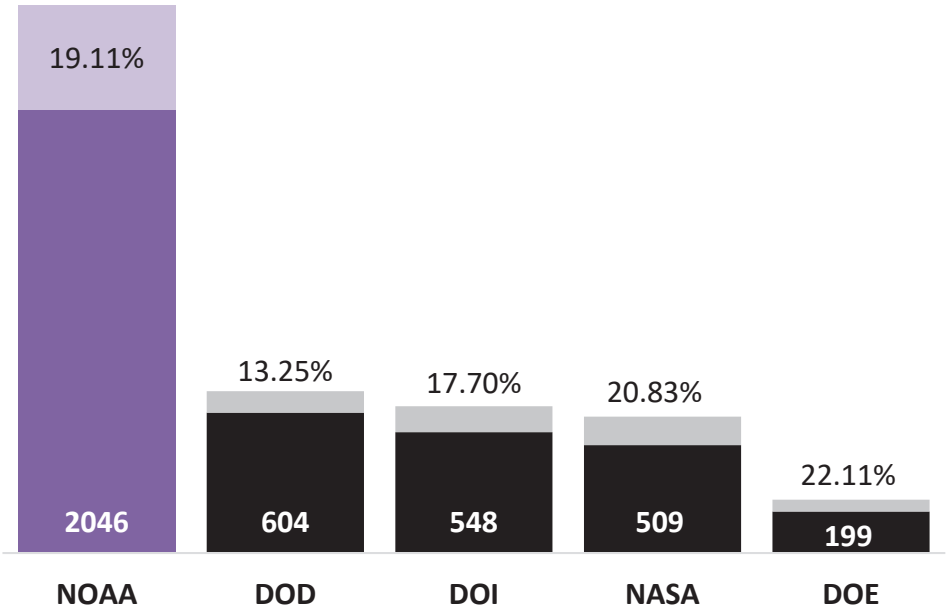
H-Index



Within the field of marine & freshwater biology, NOAA has an H-index of 53 - meaning that 53 of these articles have been cited in the peer-reviewed literature at least 53 times.

Oceanography

Total Number of Articles by Agency



Top Journals where NOAA Publishes

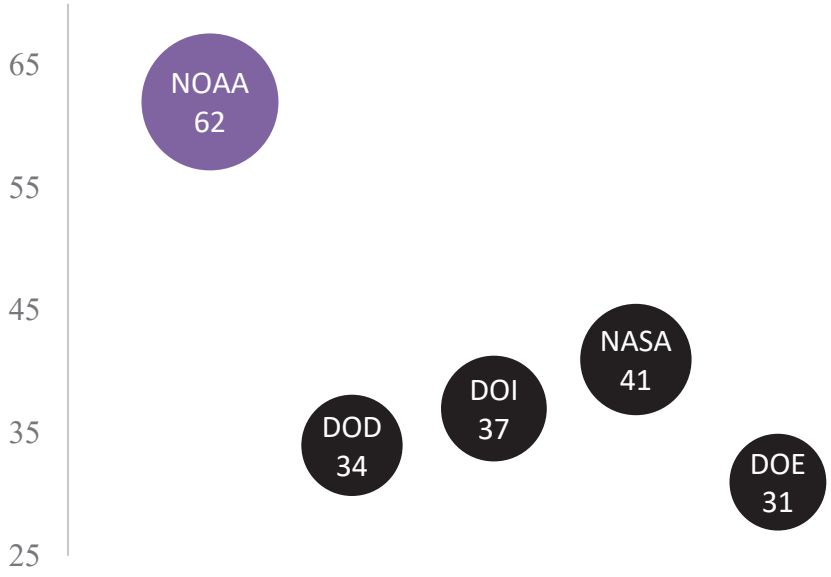
- *Marine Ecology Progress Series*
- *Journal of Geophysical Research - Oceans*
- *ICES Journal of Marine Science*
- *Deep Sea Research - Part II*
- *Ocean Modelling*

Between 2011 and 2018, NOAA published an average of approximately 256 articles per year in the field of oceanography, resulting in a total of 2046 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in oceanography.

Highly Cited NOAA Articles

- Pershing, et al. 2015. Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. *Science.*
- Resing, et al. 2015. Basin-scale transport of hydrothermal dissolved metals across the South Pacific Ocean. *Nature.*
- Balmaseda, et al. 2015. The Ocean Reanalyses Intercomparison Project (ORA-IP). *J Operational Oceanography.*

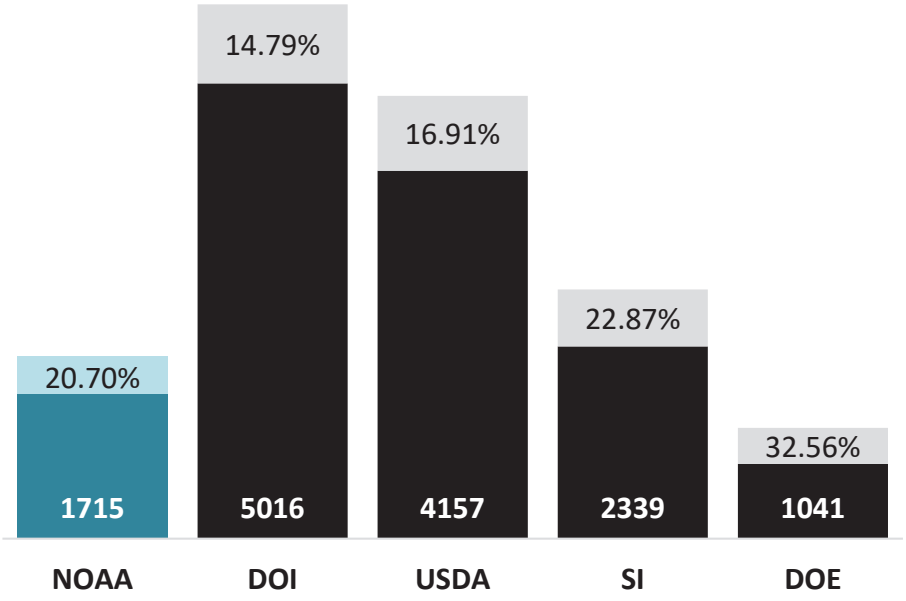
H-Index



Within the field of oceanography, NOAA has an H-index of 62 - meaning that 62 of these articles have been cited in the peer-reviewed literature at least 62 times.

Ecology

Total Number of Articles by Agency



Top Journals where NOAA Publishes

- *Marine Ecology Progress Series*
- *Biogeosciences*
- *PLOS One*
- *Proceedings of the Royal Society B*
- *Global Change Biology*

Between 2011 and 2018, NOAA published an average of approximately 214 articles per year in the field of ecology, resulting in a total of 1715 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in ecology.

Highly Cited NOAA Articles

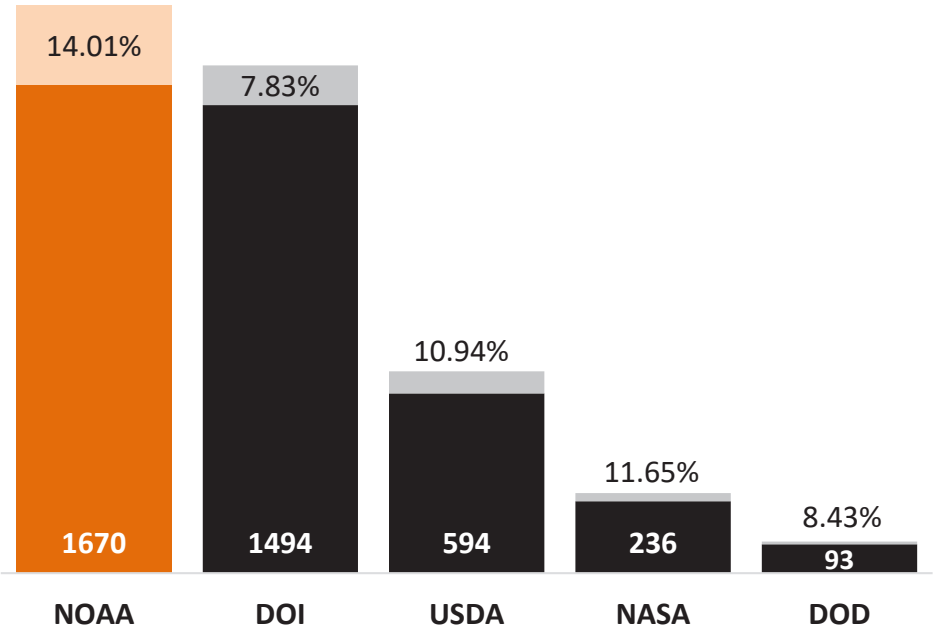
- Hughes, et al. 2017. Global warming and recurrent mass bleaching of corals. *Nature.*
- Anderegg, et al. 2015. Pervasive drought legacies in forest ecosystems and their implications for carbon cycle models. *Science.*
- MacNeil, et al. 2015. Recovery potential of the world's coral reef fishes. *Nature.*

H-Index

Within the field of ecology, NOAA has an H-index of 71 - meaning that 71 of these articles have been cited in the peer-reviewed literature at least 71 times.

Fisheries

Total Number of Articles by Agency



Top Journals where NOAA Publishes

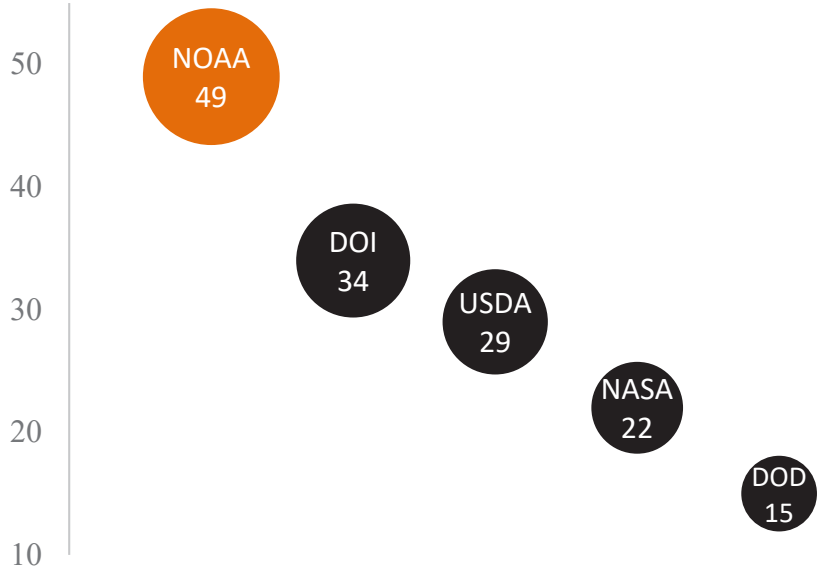
- *ICES Journal of Marine Science*
- *Canadian Journal of Fisheries & Aquatic Sciences*
- *Fisheries Research*
- *Transactions of the American Fisheries Society*
- *Fishery Bulletin*

Between 2011 and 2018, NOAA published an average of approximately 209 articles per year in the field of fisheries, resulting in a total of 1670 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in fisheries.

Highly Cited NOAA Articles

- McBride, et al. 2015. Energy acquisition and allocation to egg production in relation to fish reproductive strategies. *Fish & Fisheries.*
- Hare, et al. 2016. A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast US Continental Shelf. *PLOS One.*
- Patrick, et al. 2015. Myths That Continue To Impede Progress In Ecosystem-Based Fisheries Management. *Fisheries.*

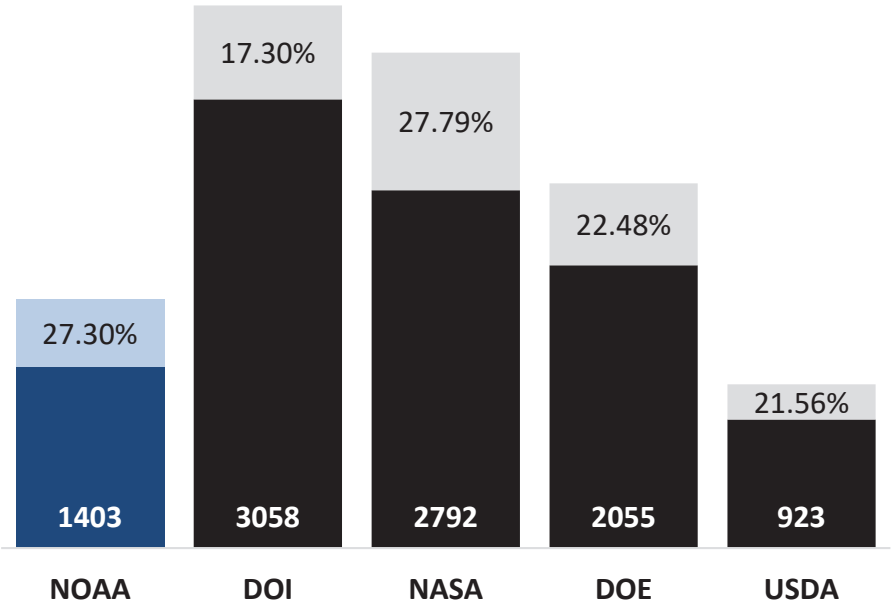
H-Index



Within the field of fisheries, NOAA has an H-index of 49 - meaning that 49 of these articles have been cited in the peer-reviewed literature at least 49 times.

Geosciences

Total Number of Articles by Agency



Top Journals where NOAA Publishes

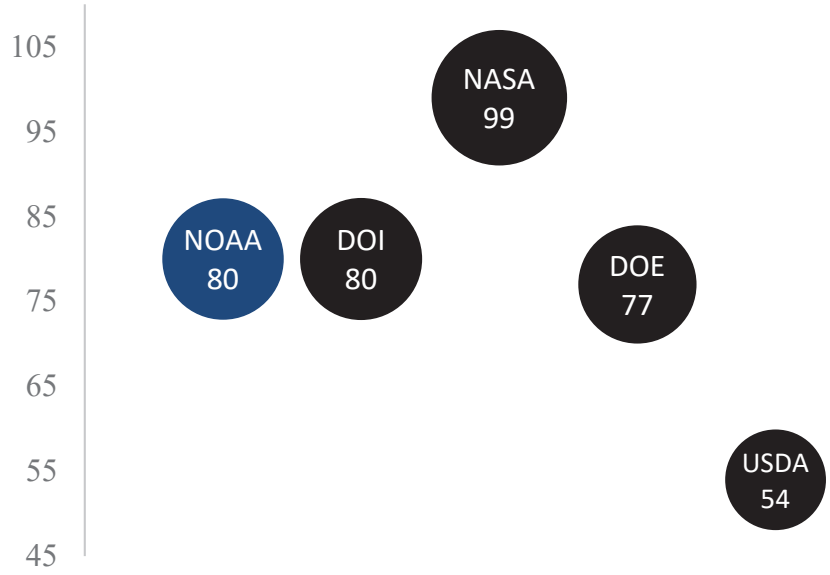
- *Geophysical Research Letters*
- *Nature Geoscience*
- *Biogeosciences*
- *Geoscientific Model Development*
- *Global Biochemical Cycles*

Between 2011 and 2018, NOAA published an average of approximately 175 articles per year in the field of geosciences, resulting in a total of 1403 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in geosciences.

Highly Cited NOAA Articles

- Homer, et al. 2015. Completion of the 2011 National Land Cover Database for the Conterminous United States. *Photo Engineer Remote Sensing*.
- Thebault, et al. 2015. International Geomagnetic Reference Field: the 12th generation. *Earth Planets Space*.
- O'Reilly, et al. 2015. Rapid and highly variable warming of lake surface waters around the globe. *Geophys Res Lett*.

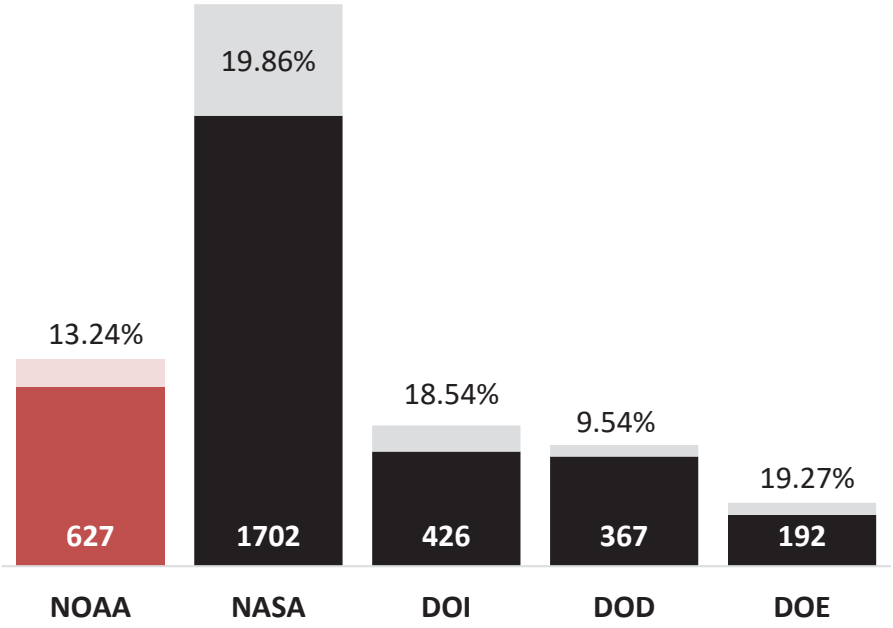
H-Index



Within the field of geosciences, NOAA has an H-index of 80 - meaning that 80 of these articles have been cited in the peer-reviewed literature at least 80 times.

Remote Sensing

Total Number of Articles by Agency



Top Journals where NOAA Publishes

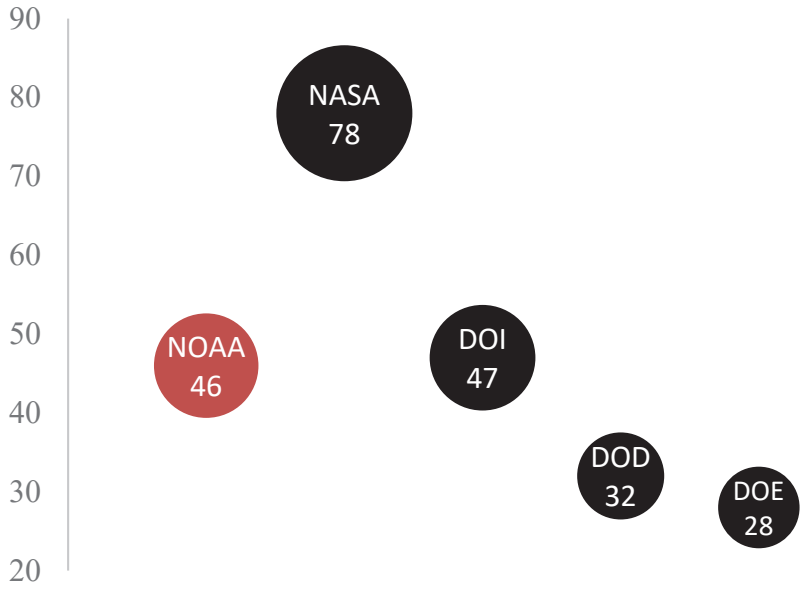
- *IEEE Transactions on Geosciences & Remote Sensing*
- *Remote Sensing*
- *Remote Sensing of Environment*
- *International Journal of Remote Sensing*
- *Journal of Applied Remote Sensing*

Between 2011 and 2018, NOAA published an average of approximately 78 articles per year in the field of remote sensing, resulting in a total of 627 articles. Also shown at the top portion of each bar is the percentage of these articles which fall within the top 10 percent of the most cited articles in remote sensing.

Highly Cited NOAA Articles

- Chan, et al. 2016. Assessment of the SMAP Passive Soil Moisture Product. IEEE Trans *Geosci Remote Sensing*.
- Kyba, et al. 2017. Artificially lit surface of Earth at night increasing in radiance and extent. *Science Advances*.
- Gua, et al. 2015. Inter-Comparison of High-Resolution Satellite Precipitation Products over Central Asia. *Remote Sensing*.

H-Index



Within the field of remote sensing, NOAA has an H-index of 46 - meaning that 46 of these articles have been cited in the peer-reviewed literature at least 46 times.

Scientific Workforce

Scientific Awards and Achievements

NOAA employees are recognized time and time again for their research and development efforts and preeminence through appointments to leadership positions in professional societies, external awards, invitations to speak at prestigious events, and more, establishing NOAA as a leader amongst Federal agencies in the majority of its principal R&D focus areas.

NOAA has developed procedures and policies to ensure that employees are encouraged to serve in an official capacity as an officer or board member of a non-profit organization. These prestigious positions give our scientists the opportunities to help frame and direct research agendas and priorities within their relevant technical communities.

As a result, NOAA now has about 30 scientists serving in these capacities, many of those doing so at the highest levels. The impact this will have on our ability to recruit and retain top scientific talent into the Federal government is quite powerful.

This list reflects only those NOAA personnel serving on boards at the end of fiscal year 2019.

NOAA Scientist	Job Title	Professional Society	Position
Michael Carver	Resource Protection Specialist, NOS	California Whale Rescue	Member, Board of Directors
Mark Chandler	Fisheries Biologist, Assessment and Monitoring Division, Office of Science and Technology, NMFS	American Institute of Fishery Research Biologists	Member, Board of Directors
John Cortinas	Director, Office of Weather and Air Quality, OAR	American Meteorological Society	Councilor
Ryan Ellis	Meteorologist, NWS	American Meteorological Society	AMS Board for Operational Government Meteorologists
Tanja Fransen	Meteorologist in Charge, Glasgow Weather Forecast Office, NWS	American Meteorological Society	Councilor
Jared Guyer	Lead Forecaster, Storm Predition Center, NWS	National Weather Association	Councilor
Wayne Higgins	Director, Climate Program Office, OAR	American Meteorological Society	Councilor
Fiona Horsfall	Chief, Climate Services Division, NWS	American Association of State Climatologists	ex-Officio Executive Board
Tamara Houston	Regional Climate Services Program Manager, NESDIS	American Association of State Climatologists	ex-Officio Executive Board

Scientific Awards and Achievements

NOAA Scientist	Job Title	Professional Society	Position
Jayme Laber	Senior Service Hydrologist, NWS	Channel Islands Regional GIS Collaborative; The California Geographic Information Association	Board Member
Deborah Lee	Director, Great Lakes Environmental Research Laboratory, OAR	ASCE Environmental Water Resources Institute	Vice-President, President-Elect, President, Past President
Christine Lipsky	Research Fishery Biologist, NMFS	Aqua Kids TV	President and Science Advisory, Board of Directors
Wayne R. Litaker	Supervisory Ecologist, NOS	International Society for the Study of Harmful Algae	Board Member
Patrick Lynch	National Stock Assessment Program Lead, NOS	American Fisheries Society - Marine Fisheries Section	Secretary - Tresurer
James Manning	Research Oceanographer, NMFS	Educational Passages	Member, Board of Directors
Jennifer McNatt	Emergency Response Meteorologist, NWS	National Weather Association	Councilor
Roy Mendelssohn	Supervisory Operations Research Analyst, Environmental Research Division, NMFS	International Biometric Society (IBS), Western North American Region	Regional Committee Member
Richard Methot, Jr.	Senior Scientist for Stock Assessments; Chair of the Council of NOAA Fellows, NMFS	American Fisheries Society - Marine Fisheries Section	President-elect, President, Past President
M. Katherine Moore	Biologist, NMFS	Society for Wildlife Forensic Science	Director of Professional Development
Shirley Murillo	Depty Director, Hurricane Research Division, AOML, OAR	American Meteorological Society	Councilor
Trisha Palmer	Warning Coordination Meteorologist, NWS	National Weather Association	Councilor
Cynthia Palmer	Meteorologist in Charge, NWS Moneterey, CA	Center for Applied Atmospheric Research and Education	Advisor

Scientific Awards and Achievements

NOAA Scientist	Job Title	Professional Society	Position
Marc Suddleson	Program Manager, National Centers for Coastal Ocean Science, NOS	Federal Laboratory Consortium	Member-at-Large on the Executive Board
David Vallee	Hydrologist in Charge, NWS	American Meteorological Society	AMS Best Practices Board Member
Chris Yates	Fish and Wildlife Administrator, NMFS	Honda Marine Science Foundation	Member, Board of Directors

One notable way that outstanding achievements are recognized is through a variety of awards. In 2019, NOAA employees and team members were recognized with external science awards for their excellence, including:

Award	Award Description	Award Organization
Gears of Government Award	The Gears of Government Awards recognize individuals and teams across the Federal workforce whose dedication supports exceptional delivery of key outcomes for the American people.	General Services Administration and the Office of Management and Budget
Service to America Medal Winner and Service to America Finalist	This award, also known as the "Sammie", is presented to honor exceptional accomplishments within the Federal service	Partnership for Public Service
NASA Goddard Space Flight Center Group Award	In recognition and appreciation of outstanding contribution to the successful development, launch, and activation of the Ice, Cloud, and Land Elevation Satellite (ICESat-2)	NASA
American Meteorology Society 2019 Award for Outstanding Contribution to the Advance of Applied Meteorology	Awarded to a NOAA scientist for a lifetime of extraordinary leadership and accomplishment in developing and implementing statistical forecasting methods for severe weather, quantitative precipitation, and lightning	American Meteorology Society
James R. Holton Award	Awarded to a NOAA scientist for recognition of outstanding scientific research and accomplishments of early career scientists in the field	American Geophysical Union
2019 Group on Earth Observations (GEO) Individual Excellence Award	Awarded to a NOAA scientist, this award is presented to "individuals who have demonstrated exceptional personal commitment to the GEO Mission and whose work has had tangible impact"	Group on Earth Observations

Scientific Awards and Achievements

Award	Award Description	Award Organization
Outstanding Nature Documentary	A NOAA scientist served as the Chief Scientific Adviser for the Netflix original documentary "Chasing Coral", which won Outstanding Nature Documentary at the 39th Annual News and Documentary Emmy Awards and features NOAA Coral Reef Watch's satellite and modeled products	Emmy Awards
Gulf of Maine Visionary Award	The awards recognize innovation, creativity, and commitment to protecting the marine environment. Recipients may work in the fields of environmental science, education, conservation or policy. They may be engaged in projects that involve public awareness, grassroots action, or business/manufacturing practices	Gulf of Maine Council on the Environment

In 2019, awards for NOAA personnel from NOAA, the Department of Commerce, and the Executive Office of the President included:

Awardees	Award	Award Organization
8 individuals	Presidential Early Career Award for Scientists and Engineers (PECASE)	Executive Office of the President
1 individual	NOAA Technology Transfer Award	NOAA
2 patents	New U.S. Patents for Technologies Developed by NOAA Employees	Department of Commerce
17 individuals representing 2 groups	Gold Medal Award for Scientific/ Engineering Achievement	Department of Commerce
25 individuals representing 5 groups	Silver Medal Award for Scientific/ Engineering Achievement	Department of Commerce
56 individuals and 3 offices representing 11 groups	Bronze Medal Award for Scientific/ Engineering Achievement	Department of Commerce
10 individuals	Distinguished Career Award for Scientific Achievement	NOAA

In addition to scientific achievement, many individuals within NOAA receive awards for leadership, professional excellence, heroism, and more. Additional award winners can be found within the NOAA Office of Human Capital Services website (e.g., Department of Commerce Gold and Silver Medals and NOAA Administrator's Award).

Diversity and Inclusion

NOAA's Diversity and Inclusion Vision

NOAA recognizes the importance of a diverse workforce to achieve our mission of science, service and stewardship. With this in mind, NOAA developed a NOAA Diversity and Inclusion Strategic Plan for fiscal years 2017-2019 to establish a framework for action to strengthen diversity and inclusion. This document defines the goals, objectives, and strategies for fostering a diverse, highly capable workforce; building an inclusive work environment; and cultivating sustained leadership commitment through accountability, data, and education.

From the NOAA Diversity and Inclusion Strategic Plan

NOAA's diversity and inclusion efforts are guided by the following vision:

An inclusive environment in which the Agency leverages diversity to achieve mission goals and business objectives and maximizes the potential of individuals and the organization

Diversity and Inclusion

NOAA's Diversity and Inclusion Goals

1. Workforce Diversity - Recruit a Diverse, Highly Capable Workforce
2. Workplace Inclusion - Build a Work Environment that Promotes Inclusion
3. Build Sustained Leadership Commitment to a Diverse and Inclusive NOAA through Accountability, Data, and Education

NOAA's Diversity and Inclusion Initiatives

The National Ocean Service

The National Ocean Service translated outreach materials into Spanish as part of their efforts to increase diversity and inclusion, as well as to improve science communication effectiveness. These materials include information about each of the National Marine Sanctuaries, nomination processes for these sanctuaries, and other background information on the NOAA Marine Protected Areas Center.

Photo credit: NOAA

The NOAA Office of Education

The NOAA Office of Education supports education from pre-kindergarten through doctoral level students and collaborates in NOAA-mission fields with universities to prepare exceptional talent, including from diverse backgrounds, playing an important role in contributing to NOAA's Diversity and Inclusion goals. This section highlights a few of NOAA's programs and their impact on the 2019 workforce.

Educational Partnership Program with Minority-Serving Institutions (EPP/MSI)

The EPP/MSI supports the training and graduation of students, increasing participation of students from traditionally underrepresented minority communities. EPP/MSI also develops eligible candidates in support of a diverse future NOAA-mission workforce and focuses on post-secondary education and research capacity development in STEM, social science, and policy fields at MSIs that are aligned with NOAA mission fields. Since 2001, EPP/MSI funding has supported 2,306 degrees: 1,371 Bachelors, 583 Masters, and 318 Ph.D.s., and 34 other (i.e., Associates and Professional degrees). Tracking program alumni is challenging and we are continually striving to improve our ability to assess and report the impact of EPP/MSI. At least 302 EPP/MSI alumni have entered Federal service as employees or contractors. Of those, 86 have joined the NOAA workforce.

Dr. DaNa L. Carlis, a graduate of NOAA's EPP/MSI, joined NOAA as a Federal employee in 2002 through the NOAA EPP Graduate Sciences Program (GSP). In 2007, Dr. Carlis completed his Ph.D. from the EPP/MSI NOAA Center for Atmospheric Sciences at Howard University in Washington, D.C. and, in 2014, Dr. Carlis was accepted into NOAA's Leadership Competency Development Program (LCDP), where he spent 18 months working as a policy advisor to the NOAA Chief Scientist and the NOAA Assistant Secretary of Environmental Observation and Prediction (ASEOP), contributing his experience in research and operations to a policy and strategy office. Today, he works in NOAA's Office of Weather and Air Quality (OWAQ) as a program manager of the Earth Prediction Innovation Center (EPIC), Dr. Carlis sits on the Equal Employment Opportunity Advisory Committee (EEOAC) as an ad hoc member to help create a fair and equitable workplace across OAR. Dr. Carlis' concern for EEO and Diversity and Inclusion is also evident in his dedication to NOAA's Diversity and Professional Advancement Working Group (DPAWG), which he helped establish in 2014 to support the advancement of underrepresented groups at NOAA.

Dr. Larry Alade is a Supervisory Research Fishery Biologist and serves as a task lead with the Population Dynamics Branch for the Northeast Fisheries Science Center in Woods Hole, MA. He joined the Population Dynamics Branch in 2008, following the completion of his doctoral degree at the EPP/MSI NOAA Living Marine Resources Cooperative Science Center at the University of Maryland Eastern Shore (UMES). In graduate school, he was accepted into the Graduate Sciences Program under NOAA EPP, which ultimately supported the completion of his degree at UMES. Participation in this program brought Dr. Alade to Woods Hole and offered exposure to the world-class science community based there. The support provided through NOAA's EPP program was instrumental in securing a career path in stock assessment. Dr. Alade is now part of a team of scientists that develop necessary research supporting the management of various finfish and invertebrates - fishery resources off the coast of Northeastern United States that contribute over $14 billion to the gross domestic product. In addition to his professional achievements, Dr. Alade is paying it forward in various capacities, through mentorship, educational training, and leadership opportunities.

EPP/MSI supports four Cooperative Science Center (CSC) awards aligned to core NOAA mission areas. Established through national competition, the CSCs collaborate in the training of post-secondary students in fields that directly support NOAA's mission. Students are required to participate in meaningful science, technology, engineering, mathematics, policy, natural resource management, and social science research at NOAA facilities with the guidance of their academic advisor and NOAA mentor. While each CSC is aligned with a primary line office, the centers partner and collaborate across NOAA in education, training, and research towards the development of candidates for the future NOAA workforce.

NOAA EPP/MSI CSC awards require completion of the NOAA Experiential Research and Training Opportunities (NERTO). Each graduate student must complete a minimum 12-week graduate internship at NOAA prior to graduation. Seventy five EPP CSC-supported students completed their graduate internships at NOAA facilities since fall 2018. Of the 75 graduate internships completed, 6 students focused their research on decision making and policy that apply directly to the NOAA mission.

2019 NCAS-M Fellow Cassandra Jean recently completed her NERTO with NOAA National Weather Service. She collected data to examine the response and recovery decisions of residents of St. Thomas and Puerto Rico to the risks and impacts of Hurricanes Irma and Maria. Image courtesy of the NOAA Office of Education.

The John A. Knauss Marine Policy Fellowship

The John A. Knauss Marine Policy Fellowship provides direct experience for graduate students to work on the latest issues in ocean, coastal, and Great Lakes management and research across the Federal government. In 2019, 2002 Knauss Fellow Catalina Martinez was honored with the Diversity Leadership in Government award at the annual Women of Color in STEM conference. Martinez worked in the NOAA Office of Exploration and Research (OER) during her fellowship year and was hired to continue working with the program. Seventeen years later, she still works as a physical scientist with OER.

The Ernest F. Hollings Scholarship

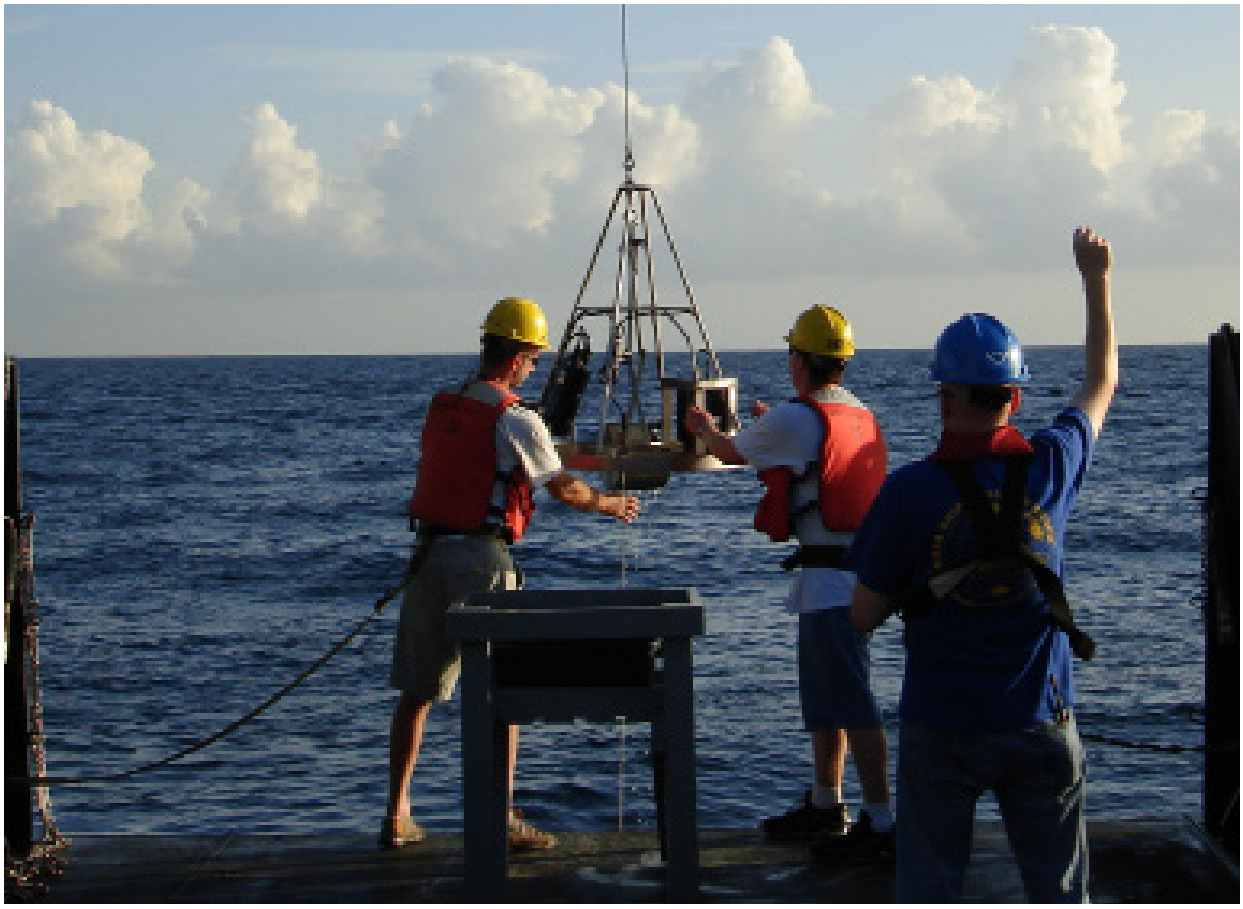
The Ernest F. Hollings Scholarship Program provides undergraduate students with a two-year academic scholarship and a paid summer internship opportunity in NOAA-related science, research, technology, policy, and education fields. In 2019, a total of 125 scholars were selected. These scholars will begin their internships in the summer of 2020.

Jordan Fuse, an undergraduate studying mechanical engineering at the University of Alabama at Birmingham, was selected as part of the Hollings class of 2018. Fuse's summer 2019 project was entitled, "Designing an interactive anomaly response training tool to improve Joint Polar Satellite System (JPSS) instrument anomaly response processes," and was conducted under the mentorship of Renee Smith Dearring at the NOAA NESDIS Office of Satellite and Product Operations. She also presented the results of her NOAA work at the 2019 NOAA Science and Education Symposium, as well as at the Young Professionals, Students, and Educators Conference of the American Institute of Aeronautics and Astronautics (AIAA) in November, where her presentation earned top honors and placed second in the Undergraduate category for Best Presentation.

Laboratory and Program Science Reviews

Individual NOAA laboratories and science programs are reviewed every five years (per NAO 216-115A) to:

- Evaluate quality, relevance, and performance of research conducted at the laboratory or the science and outreach conducted or funded by the program;
- Evaluate laboratory/program management and impact with respect to stated strategic goals, which may be defined in the laboratory/program's strategic plan or shaped by an inter-agency working group plan;
- Strategically position the laboratory/program for planning its future science;
- Ensure research is linked to the strategic plan, mission, and priorities of NOAA, the laboratory/program, and the appropriate inter-agency working group(s);
- Deliver evidence to stakeholders of the benefits of NOAA research and development;
- Report collectively on the quality of NOAA science programs;
- Identify common themes and priorities so that NOAA can determine mechanisms, policies, or actions to address corporately.



Sediment grab sampling operations. Photo credit: Travis Washburn

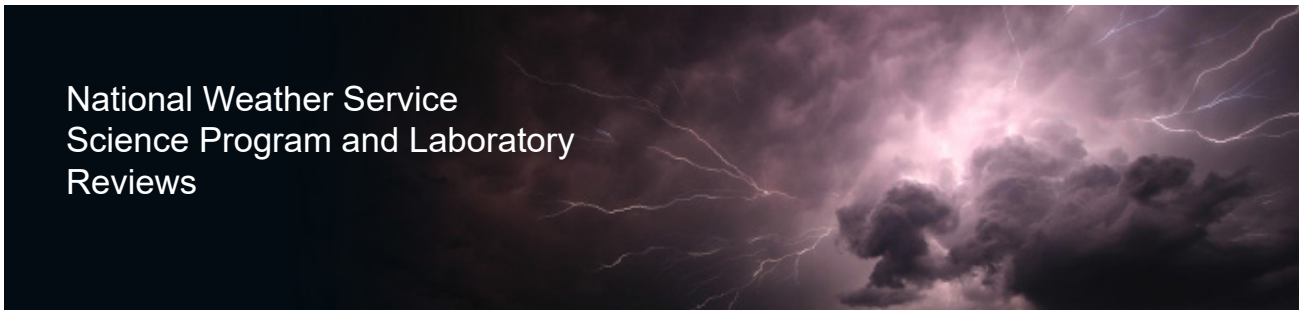
Laboratory and Program Science Reviews

NOAA NESDIS Center for Satellite Applications and Research (STAR) translates NOAA's investment in the acquisition and management of the nation's operational environmental satellites into observations for extracting knowledge, enabling analyses, predictions, and decision making for its users. STAR fulfills the critical role of calibrating NOAA satellite sensors, establishing the accuracy and quality of observations, developing algorithms to transform the satellite measurements into usable geophysical products, and validating the satellite-derived products to ensure that the criteria for intended purposes are met. STAR performs the long-term maintenance of the satellite observation algorithms, calibration, and data product quality, as well as anomaly resolution. For satellites operated by NOAA partners, STAR ensures the quality of such data streams that are employed by NOAA applications. Supporting users, STAR conducts training, user readiness, and risk reduction activities. STAR conducts applied research that advances satellite remote sensing methods, extends maturity, and develops and extends applications, thereby meeting strategic stakeholder objectives, and as well as preparing for the future by aiding formulation of next-generation sensors and data products.

NOAA NESDIS National Centers for Environmental Information (NCEI) provide data stewardship and archive environmental information produced across NOAA's missions and observing systems, as well as selected partner environmental information. NCEI produces retrospective data products that combine relevant sources of observations and environmental data into information products across all time scales and NOAA environmental domains. NCEI provides access to archived data sets and information products that enable research and development and are relevant to a broad range of users, both inside and outside the agency. NCEI conducts scientific research to advance stewardship, understand environmental phenomena, and develop information products and applications. NCEI's responsibilties span environmental domains, including meteorology, oceanography, the cryosphere, climatology, space weather, and geophysics.

An independent team of distinguished science administrators conducted an External Review of STAR research and development in March 2010, making it the first NOAA component to be reviewed under those guidelines. NCEI and its predecessor organizations—National Climatic Data Center, National Oceanographic Data Center, or National Geophysical Data Center have not been reviewed under the policy.

Laboratory/Program	Most Recent Prior Review Date
Center for Satellite Applications and Research (STAR)	2010



The National Weather Service focuses on transitioning science advancements from research partners, such as OAR labs and the external research community, into the NWS by advancing their readiness levels and implementing them into operations based on prioritized service requirements.

NOAA NWS developmental and transition organizations include the Environmental Modeling Center (EMC), Meteorological Development Laboratory (MDL), and National Water Center (NWC). In addition, the NWS field structure includes Science and Operations Officers (122) at Weather Forecast Offices, Development and Operations Hydrologists (13) at River Forecast Centers and seven science support branches located within the National Centers for Environmental Prediction (NCEP) that provide science support and transition capabilities.

NOAA NWS has regular processes to provide systematic science and management oversight and independent review for NOAA NWS developmental and transition organizations that ensure research to operations (R2O) priorities are consistent with operations service delivery requirements. These include annual planning processes for operations and budget execution, quarterly program reviews conducted by NOAA NWS senior leadership, and annual reviews of NOAA NWS operational modeling and centralized product/service suites by stakeholders, partners, and users. NOAA NWS requires transition plans for all funded R2O projects (per NAO 216-105B), to assure linkages to operations are identified at the start of each project.

NWS also has a standing community advisory group of independent scientific experts under the auspices of the University Corporation for Atmospheric Research (UCAR) to conduct annual reviews that ensure NWS models, tools, products, and services are based on sound science. Independent reviews, e.g., through UCAR, provide findings and recommendations to NWS programs that are formally addressed by relevant leadership, including a timeline of action items.

Vice President visit to the National Hurricane Center. Photo credit: Official White House Photo

National Weather Service in Key West, FL. Photo credit: NOAA

Laboratory and Program Science Reviews

In October and November 2019, NOAA Research conducted two laboratory reviews (GFDL and AOML) and one NOAA Research program review (OER). External reviewers assessed the quality of the laboratories' research and development, and they reviewed the approaches that are in place to ensure that high quality work will be performed in the future. Furthermore, they assessed progress toward meeting NOAA Research's goal to conduct preeminent research. Reviewers assessed the degree to which the research and development is relevant to NOAA's mission and of value to the Nation. Finally, reviewers assessed the overall effectiveness with which the laboratories' plan and conduct their research and development, given the resources provided, to meet NOAA Strategic Plan objectives and the needs of the Nation.

Laboratory/Program	Most Recent Prior Review Date *Note: The asterisk signifies upcoming reviews in 2020*
Geophysical Fluid Dynamics Laboratory (GFDL)	2019
Atlantic Oceanographic and Meteorological Laboratory (AOML)	2019
Pacific Marine Environmental Laboratory (PMEL)	2014*
National Severe Storms Laboratory (NSSL)	2015*
Earth System Research Laboratory Chemical Sciences Division (ESRL - CSD)	2015*
Earth System Research Laboratory Physical Sciences Division (ESRL - PSD)	2015*
Earth System Research Laboratory Global Systems Division (ESRL - GSD)	2015
Earth System Research Laboratory Global Monitoring Division (ESRL - GMD)	2018
Great Lakes Environmental Research Laboratory (GLERL)	2016
Air Resources Laboratory (ARL)	2016
Unmanned Aircraft Systems Program (UAS)	2017

Laboratory and Program Science Reviews

The National Ocean Service provides scientific data, tools, training and expertise that help communities and maritime commerce to effectively anticipate and respond to local and regional impacts of changing environmental conditions, extreme natural events, sea level changes, and coastal flooding. Ultimately, NOS research and development:

- Underpins NOAA's ability to predict and prepare for natural events and their impacts;
- Enables faster and more accurate and efficient coastal mapping and monitoring;
- Develops a multidisciplinary approach to understanding and conserving coastal and coral reef ecosystems;
- Updates numerical models and forecasting capabilities; and
- Helps assess risk.

National Centers for Coastal Ocean Science (NCCOS)

Historically, NCCOS and its preceding organizations have conducted periodic reviews of their programs and centers. A NOS-wide assessment between 2010 and 2012 provided extensive feedback and recommendations for coastal science, which initiated a realignment of NCCOS' science portfolio.

Beginning in FY17, NCCOS started cycling through annual, external peer-reviews of each of its science priorities and programs therein. These reviews have focused on program design and execution, as well as evaluation of information products and their delivery to users, and stakeholder engagement. The reviews have adopted quality, relevance, and performance as core evaluation criteria.

- Stressor Impacts and Mitigation: HABs and Hypoxia Portfolio (February 2018)
- Marine Spatial Ecology: Habitat Mapping and Biogeography Assessments (July 2019)

Review documents, including review panel findings, are posted on the NCCOS website.

National Estuarine Research Reserve System Science Collaborative

The NERRS Science Collaborative, a competitive grant program, provides dedicated funding from NOAA for research addressing the management and conservation priorities of the 29 National Estuarine Research Reserves. The results of an external review of the effectiveness of collaborative science projects, completed in October 2018 under the auspices of the University of Michigan, the administrator of the NERRS Science Collaborative, are compiled in the NERRS Science Collaborative Interim Evaluation Report.

Laboratory and Program Science Reviews

Peer Review of the Joint Hydrographic Center (JHC)

The Office of Coast Survey, along with partners from National Geodetic Survey's Remote Sensing Division, Center for Operational Oceanographic Products and Services, and NOAA Research's Ocean Exploration and Research, annually review the Center for Coastal and Ocean Mapping/Joint Hydrographic Center's past year's activities and results. The review aims to ensure that the research is on track, executed effectively, and relevant to NOAA's mission goals.

NOS Office	Laboratory/Program	Last Review Date
National Centers for Coastal Ocean Science	1. Harmful Algal Blooms and Hypoxia Portfolio	2018
	2. Habitat Mapping and Biogeography Program	2019
Office for Coastal Management: National Estuarine Research Reserve System	Science Collaborative Program	2018
Office of Coast Survey	Annual Peer Review of the Joint Hydrographic Center	2018

Sound science is critical for making the right decisions when it comes to managing our nation's fisheries and protected species. To maintain its world-class science, NOAA Fisheries continually strives to advance the science that informs fisheries and protected resources management. In January 2013, as part of ongoing improvement efforts, NOAA Fisheries began a five-year systematic peer review process at all six regional science centers and at the NMFS Headquarters Office of Science and Technology. External and internal experts carefully examine NOAA's fisheries science programs to evaluate the quality, relevance, and performance of NMFS science and research, aiming to strategically position the agency's future research and development.

For each reviewed program, independent reviewers provided recommendations that were addressed by relevant leadership in formal responses that included timelines for action items. Each year, national responses to the full suite of reviews were developed, particularly for action items best addressed at the national level.

Laboratory and Program Science Reviews

The schedule of annual reviews covered the core science program areas that directly support the NMFS mission. Over a five-year period, NMFS reviewed programs that support:

- FY13 – Data used for fishery stock assessments
- FY14 – Fishery stock assessment process
- FY15 – Protected species science
- FY16 – Ecosystem, climate, and habitat science
- FY17 – Economics and human dimensions

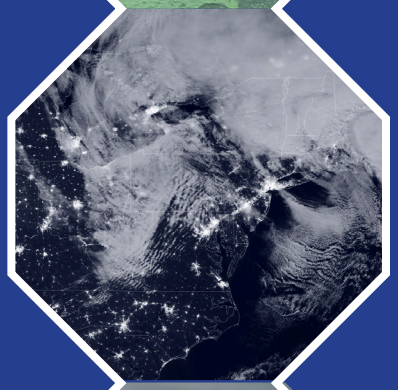
In FY18, NMFS completed a five-year review cycle covering all major science programs at the Regional Science Centers and the Office of Science and Technology. Additionally, in FY19 NOAA Fisheries released the final reports and responses from the review of the NOAA Fisheries Aquaculture Science Programs conducted in FY16 and FY17.

During FY20, NMFS will continue work on completing a strategic analysis of all program review results (34 individual reviews) initiated in FY18, with the objective of documenting lessons learned and best practices, developing approaches for better integrating science and management within regions and across mission areas, improving coordination with internal and external science and management partners, and providing strategic direction for future science.

NMFS Regional Science Centers, Associated Laboratories, and Offices that conducted science programs covered by NMFS Science Program Reviews:

NMFS Regional Science Center/Office	Associated Laboratories
Alaska Fisheries Science Center, Seattle, WA	Auke Bay, AK
Northeast Fisheries Science Center, Woods Hole, MA	Milford, CT Narragansett, RI Orono, ME Sandy Hook, NJ
Northwest Fisheries Science Center, Seattle, WA	Manchester, WA Mukiteo, WA Newport, OR Pasco, WA Point Adams, OR

Laboratory and Program Science Reviews

NMFS Regional Science Center/Office	Associated Laboratories
Pacific Islands Fisheries Science Center, Honolulu, HI	
Southeast Fisheries Science Center, Miami, FL	Beaufort, NC Galveston, TX Lafayette, LA Panama City, FL Pascagoula, MS Stennis, MS
Southwest Fisheries Science Center, La Jolla, CA	Santa Cruz, CA Monterey, CA
Office of Science and Technology, Headquarters, Silver Spring, MD	

Aerial photo of northern fur seals and Steller sea lions captured with the APH-28 hexacopter drone during aerial surveys on Bogoslof Island, Alaska, an active volcano. Photo credit: NOAA NMFS