ANNUAL REPORT



CLIMATE PROGRAM OFFICE

Advancing scientific understanding, monitoring, and prediction of climate and its impacts to enable effective decisions

CLIMATE PROGRAM OFFICE

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ON THE COVER: Aerial photograph of a magnificent braided river delta with red and green flora showing at low tide. Lower Cook Inlet in Kachemak Bay, Alaska. Credit: Mandy Lindeberg, NOAA/NMES/AKESC.



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Youth & Climate

LETTER FROM THE DIRECTOR

The demand for environmental information continues to increase across all sectors as people, businesses, and communities grapple with the growing impacts of unusual or extreme weather and climate conditions. Thoughtful, well-informed plans and preparations are required to seize opportunities, minimize risks and vulnerabilities, and hence address these challenges. Stakeholders need a suite of products and services from near term forecasts to long term projections, based on sound science and tailored to their needs, to boost economies, create jobs, and build resilience.

The Climate Program Office (CPO) is uniquely poised at the intersection of NOAA's science and service missions, the climate research community, and the broader climate enterprise, which enables it to lead a research agenda and forge partnerships that enhance society's ability to make effective decisions.

This year, in support of our mission, we reorganized CPO's divisions and are proud to introduce the Ocean Observing and Monitoring (OOM), Earth System Science and Modeling (ESSM), Climate and Societal Interactions (CSI), and Communications, Education, and Engagement (CEE) Divisions. The Administrative Services Division, our bedrock, keeps the same name. With these changes CPO is even better positioned to improve climate models, advance understanding, sustain

> climate observations, and provide data, tools, products, and services that enable effective decision making, enhance preparedness, and boost economies.

In 2016, CPO continued this vital work in many important areas:

• The CEE Division and the Sectoral Applications Research Program worked together to roll out the U.S. Climate Resilience Toolkit's Water Resources Dashboard.

- A new Mid-Atlantic Regional Integrated Sciences and Assessments team was founded.
- Two new regional Drought Early Warning Systems were established in the Pacific Northwest and Midwest to help decisionmakers better prepare for and react to drought conditions.
- A Task Force was organized to improve prediction products across seasonal and subseasonal timescales.
- A federal funding opportunity focused on the largest methane emissions hotspots in the U.S. was announced.
- A report was completed on plans for the Tropical Pacific Observing System to meet the observational, experimental, and operational needs of today and the future.

We also improved our business processes, including streamlining grants management, and advancing Integrated Information Systems that knit together our investments in observations, research, and modeling for key societal challenge areas. Societal demand for timely, accurate, and actionable information on the impacts of weather and climate has never been greater. CPO's work is focused on putting actionable data, tools, and information into the hands of those that need it to help meet this demand. The following pages in this report include just a small sample of the great work done by the CPO team. We look forward to 2017 and beyond as we continue to help people and businesses build a climate-smart nation.

K. Wayne Higgins

WAYNE HIGGINS Director, NOAA Climate Program Office

ABOUT CPO

Situated within NOAA's Office of Oceanic and Atmospheric Research (OAR), based in Silver Spring, Maryland, the Climate Program Office (CPO) advances scientific understanding, monitoring, and prediction of climate and its impacts to enable effective decisions. CPO envisions a resilient nation and world in which people, businesses, and the environment thrive in the face of climate-related changes.

CPO manages competitive research programs which fund climate science, assessments, decision support research, modeling improvements, and transition of research and capacity-building activities in four complementary and important areas:

- Observations and monitoring
- Process understanding and analysis
- Modeling, predictions, and projections
- Societal interactions and communications

While each program area has its own focus, together they demonstrate NOAA's commitment to advancing understanding of Earth's climate system through interdisciplinary, integrated scientific research, and leveraging the resulting knowledge, data, and systems to enhance society's ability to plan and respond to climate variability and climate change. CPO's network of partners, specialists, and principal investigators are working to integrate and transition research findings from CPO-sponsored research and development projects into applications designed to help communities and businesses build resilience to climate-related impacts and extreme events.

CPO MISSION

Why we exist: We advance scientific understanding, monitoring, and prediction of climate and its impacts to enable effective decisions.

CPO VISION

What we hope to achieve: People, businesses, and the environment thriving in the face of climate impacts.

Low level stratus clouds flowing around Mount Washington in New Hampshire. Credit: Ryan Knapp

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OCEAN Observing and Monitoring Division

The Ocean Observing and Monitoring Division (OOMD) works to advance understanding of the ocean's' role in driving changes in the Earth system to prepare society for environmental changes. Sponsoring thousands of global ocean observing platforms, as well as key land-based sites in the Arctic, OOMD provides high-quality, long-term observations and products to researchers, forecasters, and other users. OOMD monitors global ocean temperatures, sea level, currents, winds, weather, and acidification. Supported by OOMD, these observations allow for improved understanding of interactions influencing processes at the ocean-atmosphere interface and in the Arctic. These observations are the backbone of ocean information for weather, ocean, and marine forecasts around the world. The information that OOMD supports is critical for understanding how changes in the ocean affect phenomena such as drought and hurricanes and assets such as coastal communities, infrastructure, and transportation.

DIVISION CHIEF: DR. DAVID LEGLER

*

ARCTIC RESEARCH PROGRAM

The Arctic Research Program (ARP) provides support for maintaining and extending networks of climate observing systems around the Arctic, in collaboration with international partners.

CPO.NOAA.GOV/ARCTIC



▲ The Ocean Observing and Monitoring Divison supports moorings such as this California Current Ecosystem buoy. Credit: Scripps Institution of Oceanography ARP's observing systems measure atmospheric and oceanic temperatures, thickness of sea ice, species abundance, and biodiversity across the Arctic. Researchers use data from these systems to document the physical state of the Arctic ocean and atmosphere, along with bordering seas and coasts. The Arctic plays a key role in the climate system and ecosystems around the globe. Atmospheric and ocean warming, together with thawing permafrost, loss and thinning of sea ice, and changes in ecosystems, are associated with emerging national security issues with growing impacts on Americans and their valued assets.

Establishing the U.S. Arctic Observing Network (U.S. AON)

ARP established the U.S. AON to strategically advance the effectiveness of national observing efforts and international collaboration. Through unification of U.S. agencies and facilitation of science teams, U.S. AON proposes to maximize the value of existing observation systems. Developing systematic approaches to broaden the use of Arctic observations has been a strategic challenge within and across disciplines, as well as within and across nations.

Building and Maintaining Atmospheric Observatories

ARP continued to improve polar climate prediction and sea ice and weather forecasting using observations to measure and understand cloud properties, boundary-layer processes, and their interactions with the underlying surface (snow, permafrost, ice sheets, open ocean, and sea-ice) via exchanges of heat, momentum, and mass. The program maintains monitoring stations throughout the Arctic and works closely with modeling efforts to improve forecasts and predictions.

Arctic Report Card

ARP developed a new website to consolidate all NOAA Arctic activities and redesigned the format of the *Arctic Report Card*. Issued annually since 2006, the *Arctic Report Card* is a timely and peer-reviewed source of clear, reliable, and concise environmental information on the current state of various components of the Arctic environmental system. The report card highlights changes in the physical and biological components of the Arctic, which impact biodiversity, cultures, and economies globally. \Box

WHAT'S NEXT?

Distributed Biological Observatory: ARP will focus on advancing understanding of impacts to Arctic seasonal sea ice and waters temperature. The Distributed Biological Observatory monitors changes along the northern Bering Sea and the Barrow Sea, sampling locations of high productivity, biodiversity, and rates of biological change.

2 Developing stronger cross-NOAA partnerships: ARP is poised to deliver high-quality data products to stakeholders in NOAA's forecasting and management line offices. In the year ahead, these opportunities will focus on partnerships with stakeholders.

Building an observation network: In the next few years ARP will work to elevate its influence in order to support a pan-Arctic, multiagency, and sustained Arctic Observing Network.

4 Informing the public: ARP will continue to produce high-quality synthesis products such as the *Arctic Report Card* and arctic.noaa.gov to showcase and consolidate NOAA research activities in the Arctic.





✓ Total chlorophyll concentration across the Arctic in May 2016. Light gray indicates areas where there was no data due to clouds or ice. ARP sponsored research projects ranging from sampling of zooplankton to monitoring megafauna with acoustic samplers. Credit: NOAA Climate.gov

CLIMATE MONITORING PROGRAM

The Climate Monitoring program supports research that creates authoritative, tailored climate products and information contributing directly to the environmental intelligence of the nation.

CPO.NOAA.GOV/CLIMATEMONITORING

▼ Funded by Climate Monitoring, the Northern Hemisphere Snow Cover Extent Climate Data Record (CDR) includes data from 1966 to present and comprises the longest CDR of any environmental variable. Credit: NOAA The program documents climate variations on time scales ranging from days to centuries. These data, along with other information, support national and international climate assessments. Through collaboration with NOAA laboratories, cooperative institutes, and universities, the Climate Monitoring Program advances our ability to detect, measure, and analyze climate variability and change at regional and global scales.

ICOADS Release 3.0

The Climate Monitoring Program supported International Comprehensive



Ocean-Atmosphere Dataset (ICOADS) Release 3.0, which contains a wide range of new and improved data and metadata sources. ICOADS is the world's most extensive surface marine meteorological data collection. For the first time, it includes near-surface variables like salinity, nutrients, and dissolved carbonate chemistry. Building on extensive national and international partnerships, ICOADS provides users with easy access to many different data sources in a consistent format. ICOADS supports a variety of climate products, including the global surface temperature record, winds, pressure, humidity, clouds, and estimates of air-sea exchange.

First Release and Publication of the Last Millennium Reanalysis

Supported by Climate Monitoring, the multiyear and multi-institution *Last Millennium Reanalysis* project aims to produce state-of-the art reconstructions of the climate of the past millennium. The project provides a reconstruction of the global mean surface temperature and the spatial distribution and uncertainty



Climate Monitoring supports data sets to develop resources and information products such as hurricane databases, which help advance our understanding of extreme weather and climate. Credit: NOAA

in areas such as the temperature field. The dataset can also provide hindcast information to test models used in decadal climate predictions. Showing good agreement with past climate reconstructions and ability to pick up known climate events of ancient times, the project's first results appeared in the *Journal* of *Geophysical Research: Atmospheres*.

Developing Accessible Products

For the first time since 2014, Climate Monitoring held two competitions for new projects. In July 2016 the program solicited proposals for research that will produce observation-based products around ocean climate information, as well as global climate indicators and data for assessment. Both competitions focus on developing and improving climate-related datasets, transforming climate-related observations into informative products, and interpreting these products to better understand the current and changing state of the climate system.

High-Quality Science

In FY16, Climate Monitoring supported

research published in 39 peer-reviewed publications. Some highlights include new insights into cloud-climate relationships (by Norris et al., 2016), a paleoclimate perspective on the current California drought (by Diaz et al., 2015), and implications of climate processes for the Greenland Ice Sheet and Arctic sea ice loss (by Liu et al., 2016). □

WHAT'S NEXT?

• Supporting projects to develop a set of Global Change Indicators: These projects will help monitor the state of the climate and complement interagency efforts, such as the U.S. Global Change Research Program's Indicators System.

2 Fostering ocean climate science: New projects will promote collaboration between the ocean observing and climate modeling community, tailoring data and products that can be used in model development and diagnostic studies.

3 Paleoclimate research: FY17 will see the final results from the three-year, multi-institution *Last Millennium Reanalysis* project. The team will produce a more robust reanalysis, making the dataset available for community analyses and holding a final community workshop.

OCEAN CLIMATE Observations

The ocean moderates global temperature and atmospheric carbon dioxide, and plays a critical role in El Niño, sea level rise, drought, and tropical cyclones.

CPO.NOAA.GOV/OCO

CPO's Ocean Climate Observation (OCO) program supports research that characterizes the state of the oceans with enough detail to better understand their influence on the climate system. OCO-supported projects provide high-quality observational data for climate research, modeling, and forecasting. Working with international partners, OCO builds and maintains the in-water network of open-ocean observations around the globe. This work contributes to the Global Climate Observing System and the U.S. Integrated Ocean Observing System.

The Tropical Pacific Observing System 2020 Project (TPOS 2020)

OCO is leading sponsorship of international activities to enhance and redesign observations of the tropical Pacific Ocean. These observations are critical to NOAA's mission to improve weather and climate prediction, modeling, and forecasting. The *TPOS 2020 First Report* outlines the rationale and recommendations for the first step of the redesign and enhancement of TPOS. OCO also initiated four projects that will advance the readiness of new observing platforms and assess their potential to enhance observations of the tropical Pacific.

Pacific Rain Gauge Data

OCO continued supporting the *Pacific Rainfall Database*, which in FY16 contributed essential information to develop a set of fine resolution monthly rainfall grids. The dataset will



▲ A University of Hawaii Sea Level Center technician inspects a Global Sea Level Observing System tide gauge in Honolulu, Hawaii. Credit: NOAA

help to describe changes in Pacific rainfall as well as validate forecasts and satellite products.

Deep Argo Pilot Array

OCO helped to extend Argo into the deep ocean with support to deploy floats in the Southwest Pacific Basin. In FY16, OCO supported 8 of the 13 floats in the array. The Argo fleet comprises aquatic robots profiling the global ocean's harsh environments and depths.

Monitoring Ocean CO₂

OCO contributed to long-term surface ocean CO_2 monitoring to help quantify the ocean's role in the global carbon



▲ A California Current Ecosystem buoy being deployed that contains a sensor suite covering biological, chemical, and physical oceanography as well as meteorology. Credit: Scripps Institution of Oceanography.

budget, which enables researchers to calculate the amount of CO_2 taken up by the ocean. The Surface Ocean CO_2 Atlas (www.socat.info) version 4 product, a dataset released in September 2016, incorporates 18.5 million high-quality ocean observations from 1957 to 2015. These data and products can be used to measure changes in processes such as ocean acidification.

The U.S. Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP)

OCO supported GO-SHIP as it reoccupied one eastern Pacific and two Indian Ocean hydrographic transects. These transects are ship surveying routes repeatedly traveled over time with minimal modification to collect fulldepth ocean data. GO-SHIP decadal hydrographic transects provide unique data to determine long-term changes in the chemical and physical properties of the ocean. The cruises represent the United States' contribution to the international program. □

WHAT'S NEXT?

1 TPOS 2020: First deployments of new observing technologies to be tested under the TPOS 2020 program. Four new moored and autonomous technologies will be tested as part of the first investment for the new observing system in the tropical Pacific.

2 Global Ocean Observing System: Deployments of more than 1,300 sponsored platforms that contribute towards the Global Ocean Observing System.

3 Reviewing the Global Ocean Observing System: The World Meteorological Organization/Intergovernmental Oceanographic Commission Joint Technical Commission for Oceanography and Marine Meteorology V Session (Bali) is a meeting that brings together international delegates to review progress in implementing and maintaining the Global Ocean Observing System.

4 New wave-sensing instruments aboard NOAA Global Drifters: OCO investigators will evaluate capabilities of new wave measurements on some of NOAA's Global Drifters. This technology supports short-term climate predictions, as well as climate research and monitoring.



EARTH SYSTEMSCIENCE ANDSCIENCE ANDMODELINGDIVISION

The mission of CPO's Earth System Science and Modeling (ESSM) Division is to advance scientific understanding of Earth's atmosphere, ocean, land, and cryosphere as an integrated system and to improve NOAA's climate and Earth system models and predictions from weeks to decades. ESSM funds a unique and highly flexible research enterprise including process-level studies, predictability studies of climate phenomena, model representations of key processes and prediction technologies, development of application products, and testing for research-to-operation transitions. Conducted in coordination with NOAA labs and centers and with the national and international research community (including private sector), ESSM's research proves critical for improving NOAA's modeling and prediction capabilities. These capabilities help users and decision makers to better prepare for natural disasters, such as extremes, droughts, and coastal flooding.

DIVISION CHIEF: DR. JIN HUANG

ATMOSPHERIC CHEMISTRY, CARBON CYCLE, AND CLIMATE

The Atmospheric Chemistry, Carbon Cycle, and Climate (AC4) program supports world-class research to advance scientific understanding of the chemistry of the atmosphere.

CPO.NOAA.GOV/AC4



▲ The Earth system as seen on January 15, 2017 by NOAA's recently launched GOES-16 satellite. Credit: NOAA The AC4 program supports projects designed to observe and model gases and aerosols—and their evolution in the atmosphere—to quantify their impacts on air quality and climate. The resulting knowledge and data answer scientific and societally relevant questions about the air we breathe.

Quantifying Methane Emissions

AC4 supported research that identified and quantified methane emissions in the Four Corners region. Published in the *Proceedings of the National Academy of Sciences* in August 2016, this research quantified methane emissions from various sources in the Four Corners area, the largest methane hot spot in the United States.

Aliso Canyon Methane Leak in California

AC4 supported field measurements and actively participated in a White House

task force, providing air composition monitoring expertise. The Aliso Canyon methane leak was the largest reported natural gas leak in U.S. history. The leak extended over three months, releasing more than 100,000 tons of methane and other gases into the atmosphere and causing the evacuation of over 5,000 households near Los Angeles.

Fire Influence on Regional and Global Environments Experiment (FIREX)

AC4 funded 10 new projects consisting of 17 individual grants to universities and nonfederal research laboratories. The projects will support the FIREX campaign, led by NOAA's Chemical Science Division, which is investigating emissions and chemical transformation resulting from wildfire burning in the Western United States in FY17. □



WHAT'S NEXT?

1 Methane emissions measurements: Synthesis, analysis, and comparative study of data that will improve the understanding of the extent and influence of anthropogenic emissions of methane and other carbon gases at both national and local levels for analysis and assessment.

2 Increased focus on urban emissions: Investments under AC4 and other programs in observations of emissions from the urban environment and from oil and gas production will continue to provide new and valuable insights on how these measurements can prove useful to decision makers and other stakeholders.

3 Successful FIREX deployment and interagency coordination: Determine chemical composition of wildfire smoke plumes and their impact on air quality and human health in Western United States.



▲ Aliso Canyon methane leak in Porter Ranch, California, 2016. Credit: Earthworks

CLIMATE VARIABILITY AND PREDICTABILITY

The Climate Variability and Predictability (CVP) program supports research that enhances our understanding of the climate system through observation, modeling, analysis, and field studies.

CPO.NOAA.GOV/CVP

This vital knowledge is needed to improve climate models and predictions so that scientists and society can better anticipate the impacts of climate variability and change. To achieve its mission, CVP invests and coordinates projects with major national and international scientific bodies, NOAA laboratories and Cooperative Institutes, and other federal laboratories and academic institutions.

Robust Science

CVP-supported researchers published over 50 papers in FY16 that demonstrate the importance of improving our understanding of the physical mechanisms of the climate system and their application in improving climate models.

Improving Long-Range Arctic Sea Ice Predictions

Thanks to a project partly funded by CVP, the NOAA Climate Prediction Center (CPC) identified the cause of significant errors in their Arctic sea ice predictions. CPC developed an Experimental Forecast System to address these errors, which dramatically improved skill for sea ice forecasts tested for March–October in 2015 and 2016. Predictions from the CPC Experimental Forecast System have become a routine contribution to the *National Weather Service Alaska Region's Sea Ice Outlook*.

Improving Understanding of Atlantic Ocean Circulation

CVP funded 12 new three-year projects to support 30 researchers, postdocs, and students at 16 institutions. These projects will improve understanding of the state, variability, and change of the Atlantic Meridional Overturning Circulation (AMOC), an important driver of ocean heat transport from the Tropics to the high latitudes. AMOC has a strong influence on regional climate patterns and is being explored as a source of decadal climate predictability. These 12 projects look at new and existing observations in combination with modeling experiments to refine our understanding of the present and historical circulation (and related transports of heat and freshwater) in the North and South Atlantic. The projects represent collaborations between universities, NOAA labs, Department of Energy labs, and other nongovernmental research groups. All

of the funded Principal Investigators will become members of the U.S. AMOC Science Team.

CLIVAR Celebrates 20 Years of Progress and Hosts the CLIVAR Open Science Conference

Climate and Ocean: Variability, Predictability and Change (CLIVAR) is a network of scientists and activities around the world

that works to describe and understand the ocean's roles in climate across all timescales. In 2016, CLIVAR celebrated its 20 years of progress during their Open ► This satellite image shows the Gulf Stream current, a major component of Atlantic Meridional Overturning Circulation (AMOC), moving ocean heat from the tropics to high latitudes. Credit: NOAA

Science Conference. One of the objectives of the conference was to review the state of the science in order to prioritize international research plans and to initiate new collaborations. U.S. and international participants, including many early career scientists, attended the conference. Presentations included results from the past 20 years of CLIVAR science and future plans for the climate science community. CLIVAR is one of the four core projects of the World Climate Research Programme. NOAA support for CLIVAR and the U.S. CLIVAR Project Office comes from CVP and other CPO programs.

Engaging the Scientific Community

The CVP program hosted two public webinar series. The first of the series focused on *Understanding and Improving Prediction of Tropical Convection*. This series presented results from projects that used data collected during the international DYNAMO field campaign, including modeling and analysis studies to improve understanding and representation of important physical processes for initiation of an atmospheric disturbance known as the Madden-Julian Oscillation. The second webinar series focused on AMOC, an ocean circulation system that transports heat into the North Atlantic. Participants of this series learned about how well AMOC is represented in climate and ocean models, what physical processes drive AMOC variability, and the sources of decadal predictability of ocean and climate. Recordings of these talks are freely available from the CVP website. \Box



WHAT'S NEXT?

• Climate process field campaign in the Maritime Continent Region: CVP will select and fund projects to participate in or support activities towards observing and understanding how important atmospheric disturbances develop and evolve in the Maritime Continent Region. CVP will partner with the Office of Naval Research to perform ship-based process-level field observations and modeling experiments to better understand the ocean-land-atmosphere system. The ultimate goal of this activity is to improve subseasonal to seasonal predictions.

2 2017 U.S. AMOC Science Team meeting: The U.S. AMOC Science Team, comprised of federally funded investigators, will host a meeting in Santa Fe, New Mexico, to discuss progress made in understanding of the AMOC and to address new emerging science questions about it.

MODELING, ANALYSIS, PREDICTIONS, AND PROJECTIONS PROGRAM

The Modeling, Analysis, Predictions, and Projections (MAPP) program works to improve the nation's ability to understand and predict variability and change in Earth's climate system.

CPO.NOAA.GOV/MAPP

To achieve its mission, MAPP supports the development of advanced Earth system models that can predict climate variations and change weeks or decades into the future, as well as project longterm climate conditions over the next century and beyond. Scientists from across NOAA, partner agencies, and the external research community collaborate on MAPP-funded projects.

North American Multi-Model Ensemble (NMME)

In partnership with the NOAA Climate Test Bed, DOE, NSF, NASA, Environment Canada, and the University of Miami, MAPP transitioned the NMME to National Weather Service operations. NMME is a seasonal prediction system that combines forecasts from the leading North American climate models, with the dual purpose of providing operational guidance to NOAA's seasonal forecasts, enabling prediction research.

Advancing Subseasonal to Seasonal Prediction

MAPP supported 14 new projects to improve the prediction of phenomena on timescales from days to seasons. To accelerate progress towards this goal, MAPP convened a new Subseasonal to Seasonal (S2S) Prediction Task Force and continued

> MAPP improves estimates of extreme

weather and climate

from two weeks to a

season ahead. These

subseasonal to sea-

sonal (S2S), will ad-

vance NOAA's ability

to predict extremes,

including heat waves,

precipitation, and ex-

tratropical cyclones.

hurricanes, heavy

Credit: NOAA

predictions, known as

the Climate Model Development Task Force. The S2S Prediction Task Force includes researchers with projects in support of the new Subseasonal Prediction Experiment (SubX), an interagency experiment testing models for possible operational use by the National Weather Service to extend weather forecasts out to the midrange period.

Developed New Capabilities to Understand and Monitor U.S. Drought

Thanks to MAPP, CPO, NASA, and NIDIS support, the Evaporative Stress Index (ESI) was transitioned to opera-

tions at NOAA's National Environmental Satellite, Data, and Information Service. By combining NOAA land surface temperature data with NOAA and NASA vegetation information, the ESI provides drought warnings several weeks ahead of most other currently available drought indicators.

Setting the Stage for Improved Reanalysis Techniques

MAPP's Reanalysis Task Force concluded in 2016 after three years of coordinated effort. This Task Force focused on improved techniques that enable the next generation of NOAA reanalyses with a strong research-based foundation. The Task Force published a report summarizing their May 2015 *Technical Workshop*, which is informing NOAA planning.

Climate Forecast System Reanalysis and Reforecast Data Archive

In partnership with NOAA's National Centers for Environmental Information and National Centers for Environmental Prediction, MAPP completed a public archive of weather and climate changes over time from the *Climate Forecast System*. The dataset, which contains data from 1979–2011, stands as the most comprehensive archive of forecast data available internationally from a single system. Researchers and forecasters use it extensively to develop and improve forecast systems. □

WHAT'S NEXT?

O Subseasonal to seasonal prediction leadership and partnerships: MAPP will emphasize prediction on subseasonal and longer timescales together with its partners.

2 Exploration of seasonal prediction of coastal high water levels and marine resources: MAPP will include ocean applications in its *FY17 Federal Funding Opportunity*, including new projects to explore seasonal predictions of coastal high water levels and changing living marine resources.

3 Drought research focus: MAPP will continue work with NIDIS to advance understanding, modeling, monitoring, and prediction of drought, including new projects starting in FY17. These projects will be coordinated with the MAPP Drought Task Force, nationally the leading research group focusing on U.S. drought research.



The S2S Prediction Gap



CLIMATE AND SOCIETAL INTERACTIONS DIVISION

Communities, organizations, and businesses are looking to integrate science-based information about climate variability and change into their planning and investments. Extremes in rainfall, drought, coastal flooding, and temperature are affecting multiple sectors of society, with consequences for economies, infrastructure, the environment, and human health. NOAA's Climate and Societal Interactions Division advances research that supports planners and practitioners in understanding and managing risks influenced by changes in climate conditions. Through competitive research programs, CSI invests in research networks that connect and align cutting-edge science with the most urgent needs of stakeholders. CSI's programs leverage science from a wide range of sources to provide valuable insight for planning and preparedness, advance the use of local information in analyses and assessments, and build relationships that connect planning for today's challenges with enhancing resilience over the longer term.

DIVISION CHIEF: CLAUDIA NIERENBERG

logue

COASTAL AND OCEAN CLIMATE APPLICATIONS

The Coastal and Ocean Climate Applications (COCA) program addresses the needs of decision makers dealing with pressing weather and climaterelated issues in coastal and marine environments.

CPO.NOAA.GOV/COCA



▲ The Pacific RISA team preparing a table for a community mapping exercise for decision makers in Majuro, Republic of the Marshall Islands. Credit: Pacific RISA COCA is designed to support interdisciplinary teams of researchers in the development and transition of climate-related research and information to advance the resilience of coastal communities and coastal and marine ecosystems.

New Ecosystem Services for a Resilient Coast

COCA announced support for four new projects focusing on coastal ecosystem services for a resilient coast. These interdisciplinary, applied research projects focus on understanding the value of ecosystems and the services they provide. COCA designed the FY16 competition to build from research focused on ecosystem services funded in FY14. The goal is to provide coastal decision-makers with information on the potential role and application of ecosystem services in coastal adaptation.

Climate Impacts on Fisheries

COCA and the National Marine Fisheries Service (NMFS) Office of Science and Technology hosted the first Principal Investigators meeting for the Climate Impacts on Fisheries initiative. Held at the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, the meeting brought together researchers with NOAA scientists and decision makers in the Northeast region. Meeting participants discussed individual research projects and identified potential areas for collaboration. □



WHAT'S NEXT?

• Continuing to support regionally focused research on fisheries: The COCA Climate Impacts on Fisheries initiative released its second *Federal Funding Opportunity* (FFO) in collaboration with the NMFS Office of Science and Technology. This FFO has two competitions. The first continues to support research that informs fisheries management in the Northeast Shelf Large Marine Ecosystem. The second competition expands COCA's reach by supporting multidisciplinary research projects focused on U.S. fisheries in the California Current Large Marine Ecosystem.

2 Supporting community resilience: COCA released a competition focusing on identifying and assessing key coastal community and ecosystem risks and vulnerabilities to climate variability and change. The competition also focused on informing coastal adaptation in a changing climate.



▲ A trawler based out of Woods Hole, Massachusetts. Credit: NOAA

INTERNATIONAL RESEARCH AND APPLICATIONS PROJECT

NOAA's International Research and Applications Project (IRAP) advances an integrated program of research and capacity building designed to inform planning and risk management challenges in select regions outside of the United States.

CPO.NOAA.GOV/IRAP

IRAP supports decision-making and risk management through applied interdisciplinary research and the improved design, production, and provision of user-inspired climate information. IRAP activity streams are multiyear efforts that fully engage regional partners and comprise all of the elements of the program: vulnerability assessment, product development and provision, and monitoring and evaluation. The external IRAP team, which has also received support from the U.S. Agency for International Development, is co-led by the International Research Institute for Climate and Society of Columbia University and the University of Arizona. IRAP serves as a substantial NOAA contribution to several key international and domestic initiatives, including the *Global Framework for Climate Services* and interagency efforts to foster climate-smart development.

Enhancing Regional Climate Services

IRAP works closely with the Caribbean Institute for Meteorology and Hydrology (CIMH), which provides weather and climate information to small-island developing states in the geographically diverse Caribbean. This partnership includes a focus on the context in which climate risks affect decisions and livelihoods across the islands. The collaboration

also addresses key aspects of CIMH's information production chain by assessing supply and demand challenges, testing innovative communication forms, characterizing networks, and engaging with stakeholders. In FY16, initial findings of the collaboration appeared in Weather, Climate, and Society, a journal of the American Meteorological Society in an article titled "Connecting Climate Information Producers and Users: Boundary Organization, Knowledge Networks, and Information Brokers at Caribbean Climate Outlook Forums." The ongoing research also inspired and shaped multiple capacity-building activities, including a Social Science and Climate Services Research Seminar in Barbados and a two-week training workshop on social sciences and climate services hosted and supported by the University of Arizona. The early success of this partnership has the ability to

affect climate services in the Caribbean and inform World Meteorological Organization regional climate centers, which are a large community of international climate service providers.

Enhancing Resilience in Agriculture

Coffee leaf rust (CLR) epidemics in recent years have decimated crops in Central America and the Caribbean. IRAP researchers are collaborating with farm-

ing communities in the Blue Mountains of Jamaica, and a suite of private and public sector entities to understand the linkages of CLR with climate, and to tailor weather and climate infor-

► A local farmer harvests the iconic Jamaican Blue Mountain coffee, an important livelihood to about 120,000 that is continually exposed to climate, disease, and market stresses. Credit: Zack Guido

mation products and services that could be used to reduce the vulnerability of the coffee sector. In FY16, the IRAP team conducted baseline assessments to identify information needs and obstacles in using climate information, and synthesized key linkages between CLR and climate. These outputs set the stage for the product development, engagement, evaluation, and training activities that will occur in FY17.

Integrating Climate Information in Large Scale Development Projects

IRAP is collaborating with JEEViKA, an initiative for poverty alleviation by the government of Bihar, India, to identify and understand the value of providing climate information services to rural households, specifically to enhance resilience in flood- and drought-prone areas. In FY16, IRAP and its partners completed a comprehensive assessment of 264 villages. A team of social and physical scientists will use this information to design tailored climate products, including short and long term information, and a dissemination mechanism that will be utilized and evaluated in FY17. This project will help inform the integration of climate research and services in such development projects as those funded by the World Bank and the U.S. Agency for International Development. \Box



WHAT'S NEXT?

O Region-specific information: Expand scope and utility of climate information available in the Caribbean and Bihar, India, from weeks to months and years in advance.

2 Identify vulnerabilities: Identify the role that climate plays in creating vulnerabilities, and that climate information could play in reducing them, within the countries and regions where IRAP engages.

3 Information and services: Facilitate and study structured stakeholder engagement processes that improve climate literacy and services.

4 Resilience development: Continue to provide technical support efforts in the development community to foster climate resilience development.

5 Inform development planning: Provide technical input regarding the use of climate information products and services to the U.S. government and international development community.

REGIONAL INTEGRATED SCIENCES AND ASSESSMENTS

NOAA's Regional Integrated Sciences and Assessments (RISA) program supports regional teams that help expand the capacity of communities and organizations seeking to prepare for and respond to floods, drought, fire, extreme heat, changes in water supply and snowpack, sea level rise, storms, and melting ice and permafrost.

CPO.NOAA.GOV/RISA

The network of ten RISA teams around the country work with stakeholders and decision makers to ensure that weather and climate research and information is tailored to their decision needs.

New RISA Awards in Three U.S. Regions

RISA announced three new five-year awards for research institutions in Alaska, the Carolinas, and the Mid-Atlantic to improve the expertise and ability of decision-makers to prepare for climate-related hazards and weather extremes. The three regional teams will work closely with communities, resource managers, land planners, public agencies, nongovernmental organizations, and the private sector to enable preparedness and advance new collaborative research on how the climate will impact the environment, economy, and society.

Supporting Capacity for Regional Assessment

RISA supports three regional assessment specialists in the Pacific Islands, Urban Northeast, and Southwest regions. Together, these positions increase the capacity of RISA to support new and diverse stakeholder networks, strengthen understanding of climate impacts, and inform regional decision makers. ► Climate in Context: Science and Society Partnering for Adaptation. Credit: Wiley and Sons

In the Pacific, initial efforts have led to development of an independent, dedicated website for the Pacific Islands Regional Climate Assessment information (pirca.org). In the South Central region, partnerships with architects through a private sector global design firm and a national scale organization of professional architects are being initiated to support resilience initiatives.

New Book Highlights Positive Impacts of the RISA Program

RISA released *Climate in Context: Science and Society Partnering for Adaptation*, a book that shows the lessons and impact



Pacific RISA speaks with University of Hawaii professor Chip Fletcher (left) and the Administrator for the Hawaii Department of Land and Natural **Resources Office of Conservation Lands**, Sam Lemmo (right) at the 2016 International Union for **Conservation Nature** World Conservation **Congress about the** Hawaii Interagency **Climate Adaptation Committee. Credit: Krista Jasper**



of the 20+ year RISA program. With contributions from over 45 authors from universities, federal agencies (including NOAA), state and local agencies, and other partners, this book offers practical advice and examples for understanding context and risk, managing knowledge networks, innovating services, and advancing science policy.



 Southern Climate Impacts Planning Program RISA interns Derrick Jones and Alex Nongard. Credit: Tim Lovell

WHAT'S NEXT?

1 Learning from RISA: Strengthen evaluation of the RISA model, including coproduction research processes and approaches for actionable measurement and communication of program impact.

2 Regional Drought Early Warning Systems: Implement a new approach to regional competitions across RISA and the National Integrated Drought Information System to enhance research and engagement components of the Regional Drought Early Warning System.

3 South Central region competition: RISA will hold a competition focused on Oklahoma, Louisiana, Texas, Arkansas, Mississippi, and Tennessee.

SECTORAL APPLICATIONS RESEARCH PROGRAM

The Sectoral Applications Research Program (SARP) supports interdisciplinary research to advance understanding of how climate variability and change affect key socioeconomic sectors, and promotes the application of this new knowledge in climate-related decisions.

CPO.NOAA.GOV/SARP



SARP works with scientists, resource managers, and policy leaders to develop new tools and methodologies that they can incorporate into decision-making.

Supporting Preparedness

SARP awarded funds for six new projects focused on extreme events preparedness, planning, and adaptation within the water sector, as well as six new projects supporting the *Coping with Drought Initiative* with the National Integrated Drought Information System. This year's projects directly apply science to the decision-making process, as each project involves stakeholders, city managers, and policy makers. NOAA's scientific data and models used in these projects will be used by other organizations, communities, and entities.

Water Resources Dashboard

SARP, the National Centers for Environmental Information, and five nationally recognized nongovernmental organization (NGO) partners released the Water Resources Dashboard, a carefully curated selection of observations, outlooks, and datasets that are routinely employed by decision makers related to water-related risks and opportunities. As the Dashboard's popularity grows, so will the wants and needs of stakeholders. As such, the Dashboard will be periodically reexamined and expanded according to the needs of decision makers and availability of relevant data sets. The Dashboard is located under the water topic section in the U.S. Climate Resilience Toolkit. It can be accessed at https://toolkit.climate.gov/topics/ water-resources/water-resources-dashboard.

Informing the Public

Together with the National Centers for Environmental Information and five nationally recognized NGOs, SARP developed and coordinated a series of learning sessions to accompany the Water Resources Dashboard. Speakers in these sessions included key water utility managers from various municipalities and federal scientists from entities such as the National Weather Service, the National Integrated Drought Information System, the Federal Emergency Management Agency, and the U.S. Geological Survey.

Built Environment

SARP led the release of the Built Environment section of the U.S. Climate Resilience Toolkit. This section is designed to help address a wide range of risks facing cities and towns. Extreme events such as heat waves, heavy downpours, floods, and storm surges often result in devastating and lasting impacts to property, lives, and livelihoods. The Built Environment feature provides authoritative and peer-reviewed information, real-world case studies, science-based decision-support tools, planning guides, training courses, reports, action plans, and links to regional experts. It is freely available at https:// toolkit.climate.gov/topics/built-environment. \Box

WHAT'S NEXT?

• **Promoting engagement:** SARP is planning two roundtables with the American Planning Association to determine ways in which cities and municipalities can incorporate planning ideals into written documents, such as comprehensive plans.

2 Interagency partners: To work on urban development activities and improve interagency partnership opportunities, SARP and the U.S. Department of Housing and Urban Development will share a Knauss Sea Grant Fellow.

3 U.S. Climate Resilience Toolkit: SARP will continue to work with an interagency committee to expand the water section of the U.S. Climate Resilience Toolkit to include learning progressions for those new to and familiar with climate datasets.

Orought: SARP will continue to work with NIDIS with activities through the Drought Risk Management Research Center and grants associated with the *Coping with Drought Initiative*.



COMMUNICATION, EDUCATION, AND ENGAGEMENT DIVISION

In 2016, the CPO program formerly known as Communication and Education (CommEd) became the Communication, Education, and Engagement Division (CEE). CEE employs a wellrounded team of experts in the disciplines of science communication, formal and informal science education, public engagement, data visualization, web development, information and interface design, illustration, video production, programming of interactive and immersive media, and partnership development. These experts collaborate with other CPO divisions and programs to emphasize their accomplishments and results with communication and educational products—including websites, videos, brochures, briefing sheets, articles, posters, newsletters, and social media. CEE also collaborates with climate-relevant line offices, labs, and data centers all across the agency to produce and publish content in NOAA Climate.gov. In conjunction with the U.S. Global Change Research Program, and the 13 federal agencies comprising it, CEE produces and publishes content in the U.S. Climate Resilience Toolkit and other USGCRP products. Through these efforts, CEE hopes to enhance public climate science literacy, help people find and use climate data and decision-support tools, and help communities and businesses make informed decisions and build resilience to extreme events.

DIVISION CHIEF: VACANT

COMMUNICATION

Americans are increasingly seeking information from NOAA to help them understand and address climate-related challenges and opportunities.

CLIMATE.GOV



▲ Students watch a presentation on NOAA's Science on a Sphere. Credit: The Wild Center

Increasing Demand for Climate Data and Information

CEE's Communication programs produce and publish relevant and engaging climate science information that is easy for the public to access and understand. Visitors consistently rate our online content very highly, and visits to our websites have been growing rapidly. In FY16, Climate.gov received about 7 million visits—27% more than the previous year-while the U.S. Climate Resilience Toolkit received about 675,000 visits—a 71% increase over FY15. Likewise, we saw dramatic increases in subscriptions to our e-newsletter (730%) and social media following (Facebook: 44%, Twitter: 35%).

Informing the Climate-Interested Public

Climate.gov's News and Features team regularly produces narratives, blogs, maps, illustrations and data visualizations that explain the causes and effects of climate-related events and put them into a long-term perspective. Last year, we collaborated with the authors of two major international annual assessments on the state of Earth's climate system*BAMS State of the Climate* and the *Arctic Report Card*—to summarize and visualize key findings from both reports.

Regular Updates on El Niño

In January 2016, we published NOAA's new primary ENSO webpage for the public (www.climate.gov/enso), designed to provide authoritative scientific information on the status of the El Niño-Southern Oscillation. The site offers timely ENSO status updates with outlooks on likely future changes, discussion on observed and possible impacts, fact sheets and illustrations, and links to related resources from across NOAA and other agencies.

Intuitive, Extensible Maps and Visuals

We design and publish visuals that are attractive, easy to interpret, and readily reusable by others in their communication efforts, both within and beyond NOAA. Last year saw a dramatic increase in the rate of outside media republishing Climate.gov visuals. For example, our *Arctic Report Card* visuals were picked up by the Associated Press, *USA Today, The Washington Post, The*



 2015 State of the Climate: upper ocean heat content hits record high. Credit: NOAA Climate.gov

▼ Difference from historic average temperature since last ice age. Credit: NOAA Climate.gov cartoon by Emily Greenhalgh, inspired by Figure 1(b) in Marcott et al., 2014.

New York Post, Yahoo News, Esquire, Huffington Post, the UK Daily Mail, the Sydney Morning Herald, and many others.

Increasing Public Value for Climate Maps and Data

Climate.gov launched a redesigned Maps and Data section in March 2015, aimed at helping novice and experienced data users understand how NOAA collects, checks, and maps climate data. Since then visitor satisfaction with the section has gone up significantly, as indicated by visitor sessions (up 63%), number of users (up 60%), and total pageviews (up 83%). The section describes how NOAA collects, checks, maps, and archives environmental data, and helps users find data of interest through a visual catalog and clear explanations of popular datasets. Simple interfaces give users access to easy-to-interpret reusable maps and interactive graphs that depict the status of different portions of the climate system. The growth in number of visits and return visits shows the public's value for this section. \Box



WHAT'S NEXT?

1 More interactive maps: More interactive web maps to allow users to geospatially browse content for locations of interest, and to visualize differences or changes over time.

2 Evolve Event Tracker: Geospatially browsing and filtering of climate-related events, with previews and links to interpretive information about them.

3 Guided explorations: Guides for exploring interactive map layers to identify locations where assets may be threatened by climate-related hazards.

EDUCATION

CEE's Education program provides resources and expertise to help formal and informal educators teach about climate and energy.

CLIMATE.GOV/TEACHING

New Platform for Student Voices on Climate

Through an extensive set of *Climate Education and Literacy Initiative* partners, CEE helped coordinate and convene a live videoconference in the U.S. Center at the COP21 Conference in Paris that connected U.S. students with students from around the world in an open dialog about their views on the state of the climate system and policy options being discussed in public forums. Select students shared case studies highlighting successful actions their communities have taken to mitigate or adapt to climate-related impacts. The event successfully connected students to authoritative scientific information and resulted in about 33 million Twitter impressions worldwide.





Enhancing Standards-Based Climate Science Education Resources

In FY16, CEE helped to grow and syndicate the rigorously reviewed collection of 660 very high quality climate and energy education resources available through Climate.gov's Teaching Climate section. To increase educators' and students' awareness and use of these resources, the White House *Climate Education and Literacy Initiative* featured the Teaching Climate section in

The #Teach4Climate social media campaign promoted educational resources in preparation for the 2016 school year. December 2014. From July to September 2016, CEE worked with partners on the #Teach4Climate campaign, which reached about

754,000 people through Twitter and had over 3.1 million Twitter impressions.

Building Educators' Capacity to Teach Climate

CEE partnered with NOAA Education programs, National Science Teachers Association, WGBH, NASA, Alliance for Climate Education, and other organizations to implement numerous faceto-face and virtual programs to teach over 3,000 participants nationwide about specific education tools and strategies.



✓ Led by NOAA and other partners, the #Youth4Climate social media campaign empowered young voices and promoted an open discussion for all to join the youth call for climate actions at COP21. Credit: Jen Krester, The Wild Center

These sessions were designed to boost educators' awareness, understanding, and use of Climate.gov's Teaching Climate section and to help them incorporate climate science into their classrooms and informal education institutions.

Support Educators to Make Communities More Resilient

CEE supports and collaborates with NOAA's Climate Stewards Education Project, a facilitated community of practice created to increase educators' understanding of climate science and help them integrate science-based resources into their classrooms and afterschool programs. Expert-led webinars help educators learn climate science and teaching techniques as the basis for developing and implementing locally relevant stewardship projects with their students and communities. Over 200 educators nationwide participate in this program, and have engaged thousands of students and community members as part of their stewardship projects. In 2016, 24 educators worked with nearly 5,500 students on projects to mitigate or adapt to climate-related impacts. \Box



Part of Climate. gov's #Teach4Climate Back to School 2016 Campaign.

WHAT'S NEXT?

O Gap analysis of CLEAN collection: To identify whether and where gaps may exist in the "Teaching Climate" library of education resources.

Opploy educator learning progression: To establish a structured, ongoing series of educator engagements designed to build educators' knowledge, skill, and capacity in using "Teaching Climate" resources in their public education endeavors.

S Evolve and expand our partnerships: To help the climate science education community improve its effectiveness and scale up its reach.

ENGAGEMENT

The Engagement program is helping communities and businesses build resilience to extreme events, and supporting emerging commercial climate science-based decision-support services.

CLIMATE.GOV/ENGAGEMENT

Building Climate Resilience

▼ The interactive and open-source Climate Explorer offers county-scale maps and graphs showing observations and projections from 1950–2100. Credit: U.S. Climate Resilience Toolkit Managed by CEE, the U.S. Climate Resilience Toolkit (toolkit.climate.gov) is an interagency collaboration under the auspices of the U.S. Global Change Research Program. Its purpose is to help communities and businesses find and use relevant scientific information and decision-support tools to help them build resilience to climate-related impacts and extreme events. Last year, the team rebuilt the interactive and open-source *Climate Explorer* tool to allow users to interact with county-scale maps and graphs showing climate observations



and projections from 1950–2100. The team also added new topic sections (Built Environment and Marine), region sections (Arctic and Alaska, Northeast, and Hawaii and Pacific Islands), and a reports section containing state, local, and tribal action plans and vulnerability assessments.

Steps to Resilience

The U.S. Climate Resilience Toolkit offers a five-step framework for helping people in communities and businesses build resilience to extreme events and climate-related hazards. This framework guides users through processes of exploring climate-related threats to their valued assets; quantifying their vulnerabilities and risks; evaluating and selecting steps to address them; and implementing, tracking, and reporting on actions taken. CEE personnel led and participated in multiple webinars and live engagements designed to help planners and managers successfully work through this resilience-building process. Feedback to date has been overwhelmingly positive and is helping to guide and inform the evolution of the toolkit.



◄ Jim Fox, Director of University of North Carolina Asheville's National Environmental Modeling and Analysis Center (NEMAC), leads a resilience workshop planned with help from the U.S. Climate Resilience Toolkit's "Steps to Resilience." Credit: NEMAC

Forging and Sustaining Partnerships

CEE partners with a number of academic institutions, NGOs, professional societies, and businesses that have made it their mission to build their constituents' knowledge, skill, and capacity in finding and using science-based tools and data-including the American Planning Association, the VISTA/Ameri-Corps, Antioch University, and the Association of Climate Change Officers. Engagements through these partnerships over the last year helped scale up the U.S. Climate Resilience Toolkit's reach across U.S. regions and sectors. The toolkit has also garnered attention from collaborators outside of the United States. For example, in 2016 we advised Taiwan's Environmental Protection Agency about how to develop their own toolkit. And we are consulting with the World Meteorological Organization's Climate Services Information System in scoping and designing its new Climate Services Toolkit for weather forecast officers in select developing nations. We will document all of these efforts in a peer-reviewed special issue of *Climatic* Change with co-editors from Australia and the United Kingdom. \Box



Edward Gardiner speaks with government officials on Maryland's Eastern Shore about using the U.S. Climate Resilience Toolkit's "Steps to Resilience" to protect assets in the face of sea level rise.

WHAT'S NEXT?

1 Learning Progressions: CEE will work with its partners to develop topical and regional professional development curricula—called Learning Progressions— designed to build stakeholders' knowledge, skill, and capacity to find and use science-based tools and data in their endeavors.

2 Establishing a Resilience Ecosystem: CEE plans to help forge an open collaboration among federal science agencies, businesses, NGOs, and academia that helps communities and businesses build resilience to extreme events and that stimulates the emergence and growth of commercial markets for climate services.



INTEGRATED INFORMATION SYSTEMS

CPO programs are directed toward developing and sustaining Integrated Information Systems (IIS) that facilitate effective climate-related decision support in the public and private sector, and with our international partners.

The best known IIS is the National Integrated Drought Information System (NIDIS), which coordinates the sustained, systematic collection, analysis, and integration of relevant climate and drought information. Building on the success of NIDIS, CPO will lead the development of an additional IIS in the near term: the National Integrated Heat Health Information Systems (NIHHIS). CPO is also contributing to the development of a National Integrated Coastal Flood Information System (NICFIS) led by NOAA's National Ocean Service and National Environmental Satellite Data and Information Service.

LEAD: PAUL HIRSCHBERG

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM

The congressionally authorized and mandated National Integrated Drought Information System (NIDIS) works to improve the nation's drought early warning capacity.

DROUGHT.GOV



▲ Drought on Lake Mead, June, 2010. Credit: U.S. Geological Survey Since 2006, NIDIS has provided the best available information and tools for people to manage drought-related risks, assess potential impacts of drought, and prepare for and mitigate the effects of drought.

New and Expanded Drought Early Warning Information Systems (DEWS)

NIDIS launched two new regional DEWS in the Pacific Northwest and Midwest, and expanded the DEWS in the West. NIDIS coordinated federal, tribal, state, and local agencies and orga-

nizations to develop regional strategies for resilience to drought and high-precipitation events in these two regions, adding them to the six other DEWS that are active in the Coastal Carolinas, Apalachicola-Chattahoochee-Flint River Basin in the Southeast, Southern Plains, Intermountain West, Missouri River Basin, and California-Nevada. The Intermountain West DEWS is an expansion of the former "Upper Colorado" DEWS, to include Arizona and New Mexico along with the original three states: Colorado, Wyoming, and Utah.

Development of DEWS Strategic Plans

In accordance with Public Laws, NIDIS and its partners coordinated regional stakeholders to define actions for each DEWS to pursue through 2020, in support of drought early warning, planning and preparedness, and long-term resilience.

Drought.gov

NIDIS redesigned drought.gov, the U.S. Drought Portal and flagship website, in April 2016. The Cooperative Institute for Research in Environmental Sciences (CIRES), a partnership of NOAA and the University of Colorado Boulder, conducted usability studies of the redesigned site. Together with regular reporting of Google analytics on site usage, the information will be used to designate further priorities in the development of the site.

Indicators, Indices, and Triggers Workshop

NIDIS and the Drought Risk Management Research Center at the National Drought Mitigation Center, funded through CPO's Sectoral Applications Research Program, worked together to present a first-of-its-kind training and discussion of the indicators that point to a drought, the indices that quantify it, and identification of the observations and monitoring data which can inform the definition of specific triggers to help define when decision makers should take action in response to drought conditions.

Northeast Drought and Climate Outlook

Exceptional drought conditions developed over the spring and summer 2016 in New England and the Northeast, a region unaccustomed to dealing with such extremes. Outlooks for the winter showed little indication of improvement. In response, NIDIS coordinated a *Drought and Climate Outlook* forum in Boston in October, convening more than 90 state drought coordinators, researchers, climatologists, decision makers, and others to discuss the conditions, the outlook, drought response, and planning.

Ongoing Informational Webinars and In-Person Outlook Meetings

NIDIS coordinated public forums in many regions of the nation, with events in Arizona, Colorado, California, Oregon, Minnesota, Iowa, Illinois, Ohio, and Alabama. NIDIS also supports monthly and biweekly conditions updates and outlooks online through webinars, tapping experts from the National Weather Service, regional climate centers, academic institutions, river forecast centers, USDA, USGS, state climatologists, and others.



National Soil Moisture Monitoring System Development

In May, NIDIS, the USDA Natural Resources Conservation Service, and other partners convened experts to further advance the establishment of a coordinated national network of soil moisture monitoring data, including private sector activities and citizen science initiatives.

▲ Drought-related tree mortality in Sequoia National Park, California, 2015. Credit: USGS

WHAT'S NEXT?

Drought Early Warning Information Systems (**DEWS**): Explore developing a DEWS in the Northeast United States.

2 Drought.gov: Enhance drought.gov user access to information on drought conditions, planning, mitigation, research, and recovery.

3 Impacts: Enhance the understanding of the economic, societal, and ecological costs and benefits associated with risk management decision tradeoffs to mitigate drought impacts across timescales.

4 Indicators: Accelerate research efforts of drought indicators, such as soil moisture and evaporative demand, and investigate how they may be improved and integrated into drought assessments.

NATIONAL INTEGRATED HEAT HEALTH INFORMATION SYSTEM

The National Integrated Heat Health Information System (NIHHIS) was created to improve societal resilience to extreme heat and to reduce associated health consequences, such as heat illness, reduced labor productivity, and heat stroke and death.

CPO.NOAA.GOV/NIHHIS

▼ People in New York City cooling off during a heat wave in summer 2010. Credit: Vasilios Sfinarolakis Launched in summer 2015 as a joint Centers for Disease Control and Prevention and NOAA initiative, NIHHIS now unites the efforts of many U.S. Government agencies including the EPA, OSHA, and HHS, as well as university researchers and practitioners in urban planning, public health, and



other disciplines. NIHHIS harmonizes and enhances these efforts by running regional pilots to understand local and regional decision-maker needs, building an interagency web portal to exchange codeveloped information, and building capacity through other activities such as planning a student exchange program.

NIHHIS Website

NIHHIS launched an interagency web portal, which serves as the nexus for heat-health information from entities such as NOAA, CDC, FEMA, DOD, OSHA, NIH, EPA, the Office of the Assistant Secretary for Preparedness and Response, and the Substance Abuse and Mental Health Services Administration. NIHHIS directs decision makers to case studies, tools, training, reports, and other resources that inform decisions on reducing heat-related risk. During the heat waves that followed the launch of the NIHHIS website in summer 2016, the White House pointed to NIHHIS as the nation's "one-stop shop" for heat information. The website is available at https://toolkit.climate.gov/nihhis.

First NIHHIS Regional Workshop

NIHHIS held its first transboundary (United States: Mexico) regional workshop in El Paso, Texas, to understand the character of heat risk, vulnerability, and needs, which are unique to the region, and to improve climate and weather information that supports resilience to extreme heat. A series of workstreams worked to understand historical climate and vulnerability; inform longterm infrastructural improvements; improve outlooks, predictions, and early warning; build community capacity and engagement; and better understand the physical climate and weather drivers of health outcomes. The workshop report and executive summaries were published in English and Spanish.

Fostering Partnerships

NIHHIS expanded CPO's public footprint and partnerships through engagements with the State Department in Singapore to train member countries of the Association of Southeast Asian Nations on climate and health topics, including extreme heat. NIHHIS also engaged in meetings in India, the International Network on Climate and Health in Africa, and the first climate and health focused Climate Outlook Forum in Sri Lanka. NIHHIS also participated in the Design for Risk Reduction Symposium in New York City. Further, NIHHIS was proposed as a starting point for the creation of a new international network to accelerate progress on extreme heat risk mitigation. This initiative will be called the Global Heat Health Information Network.



CPO Director Wayne Higgins speaks at the National Integrated Heat Health Information System Workshop in Chicago. Credit: NOAA

WHAT'S NEXT?

Continuing growth: NIHHIS will continue to grow its national presence in regions including the Northeast (New York City and New England), Midwest (Chicago to Minneapolis, and surrounding areas), Northwest (Seattle), and the West through new pilot launches and other activities to understand and harmonize approaches to extreme heat resilience. Ultimately, NIHHIS will be essential in preparing these regions for heat seasons with timely information to reduce morbidity and mortality associated with heat extremes. Where possible, these pilots will be transboundary, collaborating with existing Mexico and Canada partnerships organized by CPO's International Partnerships team.

2 Increased capacity: NIHHIS will continue to evolve its capacity to offer skillful and useful predictions and projections for heat and humidity extremes for subseasonal to decadal timescales, engaging partners nationwide to ensure and grow resilient practices in all NIHHIS regions. Additionally, the collective capacity of NIHHIS partners will evolve, as this interagency platform harmonizes efforts to work efficiently in reducing heat risk for Americans.

3 The Global Heat Health Information Network (GHHIN): Through GHHIN, NIHHIS will inform a new global partnership intended to accomplish many of NIHHIS's national goals with international partners. GHHIN will launch in 2017 with many of the same partners NIHHIS convened in its launching workshop in Chicago in 2015, including those from Germany, India, Canada, Mexico, Australia, and the United Kingdom. The purpose of GHHIN will be to leverage existing local, state, national, and multinational research, interventions, and data to advance heat risk resilience globally.

ASSESSMENTS

The Assessments program aims to improve our ability to describe and enable effective responses to the impacts and vulnerabilities associated with environmental change in the United States.

CPO.NOAA.GOV/ASSESSMENTS

The program supports climate assessments at national and regional scales that are based on the latest climate research, connects institutions and activities in different regions and sectors, and creates networks of scientists and decision makers.

NOAA Leadership of the Fourth National Climate Assessment (NCA4)

The Assessments program secured and organized NOAA's leadership of the NCA4, due in 2018. As the interagency administrative lead, NOAA leads the technical production of the report and contributes specific scientific leadership to eight chapters in it. Five NOAA Line Offices contribute to the report (OAR, NESDIS, NMFS, NOS, NWS). NOAA led the development of a model for authoring NCA4 without using a Federal Advisory Committee while ensuring extensive and proper involvement of the external community.

Climate Science Special Report (CSSR)

The Assessments program coordinated NOAA's leadership of the CSSR. A major foundational input to the *Fourth National Climate Assessment*, CSSR will describe the state of physical climate science knowledge. A draft of the report that was prepared in FY16 will be finalized in FY17.

Sustained Assessment Coordinators

Partnering with the CPO's RISA program, the Assessments program initiated support for Sustained Assessment Coordinator positions in three RISA groups: Pacific RISA, Western Water Assessment, and the Consortium on Climate and Risk in the Urban Northeast. These Coordinators will enable National Climate Assessment capacity and engagement. They will also connect the work of the RISA teams with the sustained assessment process. \Box

WHAT'S NEXT?

1 Finalizing the *Climate Science Special Report* (CSSR): After a round of public review and final edits, the CSSR will be released in FY17 as input for the NCA4.

2 Writing underway: In FY17, NCA4 author teams will organize and produce the first draft of NCA4, which will undergo a number of rounds of public and interagency review.

3 Indicators: The Assessments program will work to advance the pilot interagency indicators system in FY17, making updates to the system, including new indicators, and connecting the indicators system to the Assessment development process.



 Created in part with support from the Assessments program, this indicator shows annual heating and cooling degree days in the contiguous United States. Credit: NOAA and U.S. Census Bureau



INTERNATIONAL COORDINATION AND PROJECTS

Recognizing that climate variability and change are global concerns, CPO is actively working with international partners to advance climate science and services.

CPO.NOAA.GOV/INTERNATIONAL

▼ CPO's Meredith Muth (second from left) briefing the International Board on Climate Services. Credit: Meredith Muth CPO's contributions to NOAA's international research enterprise aim to improve global observation capabilities, enhance jointly-produced transboundary information products, improve scientific capacity in partner countries and international institutions, identify global research priorities and best practices, and inform future directions and



strategic plans of the international community. Beneficiaries of CPO's international activities and engagement include international science programs, global observation networks, climate information providers, scientific and academic institutions, and U.S. agencies.

CPO has a strong focus on strategic partnership-building at a global scale to strengthen our own domestic investments while informing international priorities related to climate science and services. These partnerships are designed to advance climate observations and research; connect U.S. climate science experts, tools, and services with international needs and expertise; provide expertise and leadership for international scientific programs; and represent the United States and NOAA on climate-relevant bilateral, regional, and global partnerships.

Convening Transboundary Collaborations

CPO leadership on the North American Climate Services Partnership fostered improvements in the development of products and services through international collaboration. For example, the North American Drought, Wildfire, and Climate Services Forum addresses synergies and opportunities in the areas of drought monitoring, fire forecasting, and transboundary climate services in the United States, Mexico, and Canada. CPO also led in the establishment of a United States and Mexico regional pilot for the National Integrated Heat Health Information System along the Rio Grande-Rio Bravo region. CPO also supports the North American Multi-Model Ensemble project, which has led to improvements in seasonal forecasting and freely available data—currently the only one of its kind-to the national and international community.

Developing Key International Priorities Related to Observations, Science, and Services

CPO played a leading role in the finalization of the 2016 Global Climate Observation System Implementation Plan, the 2016–2018 Priority Needs for the Operationalization of the Global Framework for Climate Services, and the launch of the Global Heat Health Information Network. CPO also engaged with U.S. and international colleagues to support the Years of Maritime Continent in 2017–2019 and the international subseasonal to seasonal prediction project.

Facilitating Climate Information for the U.S. and Global Community

CPO continued to lead efforts under the World Meteorological Organization to develop a Climate Services Information System that will be relevant for global, regional, and national partners. Key accomplishments in 2016 include advancing development of national-level climate services toolkits across the globe that build on experiences from the CPO-led *U.S. Climate Resilience Toolkit* and other web platforms. □

WHAT'S NEXT?

1 Inform international research priorities and best practices: Ensure that CPO expertise continues to strategically engage in key international bodies in order to identify global scientific priorities and inform future CPO investments.

2 Expand global ocean observations with international partners: Strengthen and support international partnerships that allow CPO and the United States to coordinate and leverage work from international partners in sustaining and expanding global observations.

3 Accelerate implementation of heat-health priority actions with international community: The Global Heat Health Information Network serves as an international platform to promote the development and use of integrated climate, weather, and health information for synergistic, evidence based policy and actions to improve the management of extreme heat risks.

4 Strengthen U.S. interagency cooperation on international-relevant activities: CPO will continue to play a strong coordination and convening role in promoting cooperation with other U.S. agencies in support of U.S. international priorities for resilient development or other international obligations. Examples include providing leadership to several interagency groups such as the U.S. Global Change Research Program; supporting the Environmental Protection Agency in meeting U.S. commitments under the United Nations Framework Convention for Climate Change (UNFCCC); and identifying strategic areas of collaboration with other agencies.

RESOURCES AND ACHIEVEMENTS



▲ Map of all states receiving funding from CPO for FY16 new competitive awards. Shades of blue represent numbers of projects, and bold numbers show grant amounts awarded by CPO in FY16 (in thousands of dollars).

FY16 ACHIEVEMENTS (quick stats)

Competitions held: 10 New projects: 73 Ongoing projects from past competitions: 137 New publications supported: 836

REPORTS/PUBLICATIONS

Compo, G. et al. January 2016. *Report* from the NOAA Climate Reanalysis Task Force Technical Workshop. NOAA Technical Report OAR CPO-4.

Cravatte, S. et al. 2016. *First Report of TPOS 2020*. GOOS-215.

Kinter, J. et al., U.S. Dept. of Energy, and NOAA. March 2016. *High-Resolution Coupling and Initialization to Improve Predictability and Predictions in Climate Models Workshop*. DOE/ SC-0183. NOAA Technical Report OAR CPO-5.

Huang, J. et al. NOAA Drought Task Force. 2016. *Research to Advance National Drought Monitoring and Prediction Capabilities*.

United States Mid-Century Strategy for Deep Decarbonization.

Muth, M. and J. Shumake-Guillemot. June 2016. 2016–2018 Priority Needs for the Operationalization of the Global Framework for Climate Services.

NACSP. 2016. North American Climate Services Partnership Annual Accomplishment Report.

NIDIS and Desert Research Institute. October 2015. *Wildfire and Drought: Impacts on Wildfire Planning, Behavior and Effects.*

NIDIS. March 2016. Western States Drought Coordinators and Emergency Managers Meeting: Report and Next Steps.

Parris, A.S. et al. April 2016. *Climate in Context: Science and Society Partnering for Adaptation*. American Geophysical Union. Wiley and Sons. Richter-Menge, J., J.E. Overland, and J.T. Mathis, Eds. 2016. *Arctic Report Card 2016*.

Riley, R. and A. Krautmann. 2016. *Managing Disaster: 20 May 2013 Central Oklahoma Tornado*. Southern Climate Impacts Planning Program.

RISA. 2016. 2016 Annual Meeting Report.

Water Resources and Climate Change Workgroup. November 2016. Looking Forward: Priorities for Managing Freshwater Resources in a Changing Climate. National Action Plan Update. S60.0 million ▲ CPO's programs and activities are funded primarily through three NOAA budget line items, which can be found in NOAA's budget documents. In FY16, the budget line items were: Regional Climate Data and Information (RCDI); Climate Competitive Research (CCR); and Sustained Ocean Observa-

tions and Monitoring (SOOM).

CCR

RCDI

\$38.0 million

SOOM

\$41.3 million

The White House.

November 2016. United States Mid-Century Strategy for Deep Decarbonization. Chapter 5: Storing Carbon and Reducing Emissions with U.S. Lands, Wetlands.

World Meteorological Organization. 2016. 2016 Global Climate Observing System (GCOS) Implementation Plan.

NEWSLETTERS

Alaska Climate Dispatch. Published quarterly by ACCAP RISA.

Carolinas Climate Connection. Published quarterly by CISA RISA.

Changing Ice Newsletter. Published biannually by ACCAP RISA. *The Climate CIRCulator*. Published monthly by CIRC RISA.

Dry Times. Published quarterly by NIDIS.

MAPP Newsletter. Published quarterly by MAPP.

NOAA Climate Connection. Published monthly by CEE.

Northwest Climate Magazine. Published annually by CIRC RISA.

The Observer: OOM Community Newsletter. Published monthly by OOM.

Southern Climate Monitor. Published monthly by SCIPP RISA.

The Southwest Climate Outlook. Published monthly by CLIMAS RISA.

This Week on Climate.gov. Published weekly by CEE.

WORKSHOPS

(sponsored and/or led by CPO)

October 2015. TPOS-2020 Steering Committee meeting. Hobart, Australia.

November 17–18, 2015. El Niño 2015 Conference: Shared Experiences—20 Years of Climate Services and Framing the Next Steps in the Research and Development for Climate Resilience. Palisades, NY.

January 2, 2016. Public Forum on the 2nd State of the Carbon Cycle Report (SOCCR-2). Washington DC.

January 20–21, 2016. Pacific Anomalies Workshop. Seattle, WA.

February 2–3, 2016. Pacific Northwest Drought Early Warning System Kickoff Meeting. Portland, OR.

February 2–4, 2016. Sea Ice Modeling Workshops. Boulder, CO.

February 9–11, 2016. Midwest Climate Outlook and Drought Early Warning System Kickoff Meeting. St. Louis, MO.

February 23–25, 2016. RISA 2016 Annual Meeting. Tucson, AZ.

March 9–10, 2016. U.S. Climate Modeling Summit. Washington, DC.

April 13–14, 2016. Workshop on Sustained Observations for Carbon Cycle Science and Decision Support. Boulder, CO.

April 18–19, 2016. Global Framework for Climate Services: Task Team meeting on the Operational and Resource Plan. Geneva, Switzerland.

April–August, 2016. NOAA Climate Stewards Climate Science Education Workshops. Long Beach, CA; Detroit, MI; Salt Lake City, UT; Boulder, CO; New Orleans, LA; Charleston, NC.

May 2016. COCA Climate and Fisheries Principal Investigators Meeting. Princeton, NJ.

May 24–26, 2016. National Soil Moisture Network Workshop. Boulder, CO.

June 21–23, 2016. 2016 North American Drought, Wildfire and Climate Services Forum. Forth Worth, TX.

July 13, 2016. Blue Carbon Workshop: A Management Tool for Conservation and Restoration of Coastal Wetlands. San Juan, PR.

July 13, 2016. Developing an Integrated Heat Health Information System for Long-Term Resilience to Climate and Weather Extremes in the El Paso-Juárez- Las Cruces Region. El Paso, TX.

August 10–11, 2016. Forecasting ENSO Impacts on Marine Ecosystems of the U.S. West Coast Workshop. San Diego, CA.

September 12–14, 2016. 2016 Carolinas Climate Resilience Conference. Charlotte, NC.

September 18–23, 2016. CLIVAR Open Science Conference. Qingdao, China.

September 26–27, 2016. Drought Indicators and Triggers Workshop. Boise, ID.

September 28, 2016. White House Arctic Science Ministerial. Washington, DC.

October 5–6, 2016. Pathways to Adaptation: Ocean Acidification in the Arctic Workshop. Helsinki, Finland.

October 5–6, 2016. GLISA Great Lakes Adaptation Forum. Ann Arbor, MI.

October 13–14, 2016. Texas and Oklahoma Climate Extremes Workshop: Learning from the Recent Four-year Drought and Spring Flooding Events. Fort Worth, TX.

October 25–28, 2016. Tropical Pacific Observing System 3rd Steering Committee Meeting (SC-3). Lima, Peru.

November 14–16, 2016. 7th Annual Northwest Climate Conference. Stevenson, WA.

December 5, 2016. S2S Prediction Task Force Kickoff Meeting. Palisades, NY.

December 6–7, 2016. Sub-Seasonal to Seasonal Predictability of Extreme Weather and Climate Workshop. Palisades, NY.

