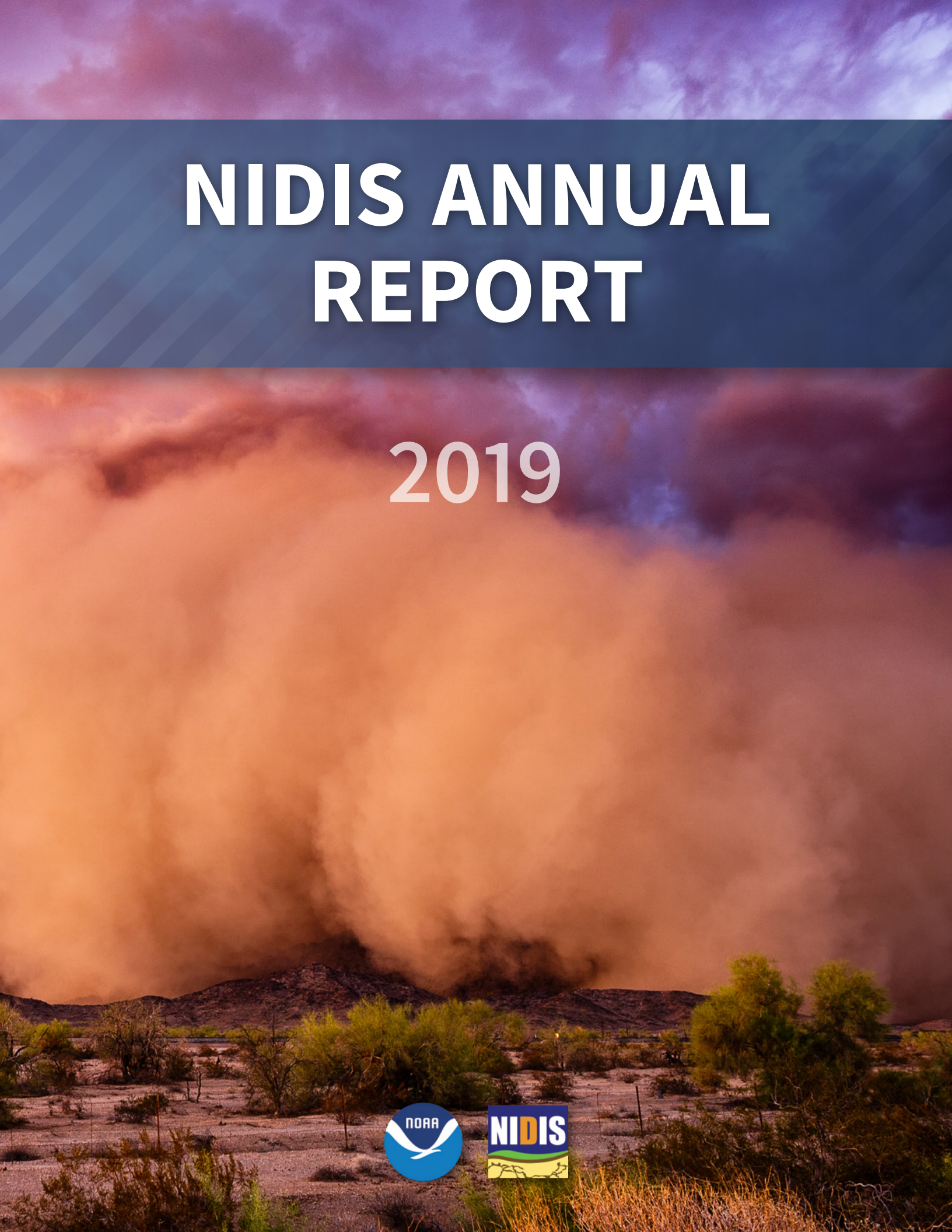
NIDIS ANNUAL REPORT

2019



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2019 Annual Report
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Cover image: Haboob dust storm in an Arizona desert. Credit: John D. Sirlin

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LETTER FROM DIRECTOR

We are excited to release our first Annual Report of the National Integrated Drought Information System (NIDIS) to provide insight into the many accomplishments of the program over the previous year and the opportunities that lie ahead.

In 2019, the United States felt the impact of droughts across Southeastern Alaska, the Pacific Northwest, numerous Southwestern and Plains states, and a widespread flash drought in the Southeast and Tennessee and Ohio Valleys. Yet, it was also one of the wettest years in U.S. history. Most of the Missouri River Basin was drenched with record-breaking precipitation and never reached abnormal dryness. Record flooding along the Mississippi River Basin took a toll on communities up and down the river corridor, costing an estimated $6.2 billion in losses. These events remind us of the need to better prepare for extreme events, and of why NIDIS and our partners must continue to advance the science and deliver accurate, earlier warnings of drought to mitigate its devastating impacts.

Recognizing these critical issues, Congress passed the NIDIS Reauthorization Act in 2018 and the bill was signed into law in January 2019, kicking off a banner year for the program and setting an ambitious agenda for the future. The law reauthorizes NIDIS through FY2023 and calls upon us to engage with the private sector to improve drought monitoring, forecasting, and communication; to utilize monitoring by citizen scientists; to support improvements in seasonal and subseasonal forecasting; to disseminate information products that show watershed differences in drought conditions; and to develop a strategy for a national coordinated soil moisture monitoring network.

We acted quickly on this mandate and infusion of support from Congress. The National Coordinated Soil Moisture Monitoring Network Executive Committee, formed in 2018, was charged with identifying a roadmap forward and the resources needed for implementing a network that will provide coordinated, high-quality, nationwide soil moisture information. In July, NIDIS co-hosted the second National Drought Forum, convening high-level decision makers to review progress made in responding to drought, to promote partnerships with U.S. businesses around drought, and to determine priority actions around drought early warning and long-term resilience issues.

These and many other achievements made for a year filled with advances in drought information delivery, research, and partnership-building, all of which I hope you enjoy learning more about in this report. We have lofty goals and a big agenda set for the year ahead, and we remain thankful to our network of partners across the country who are so vital to the realization of NIDIS's mission.

Sincerely,

Veva Deheza
Executive Director
NOAA NIDIS

ABOUT NIDIS

In 2006, the National Integrated Drought Information System (NIDIS) Act (P.L. 109-430) was signed into law, calling for the development of a national drought early warning system to collect information on the key indicators of drought in order to provide timely and relevant forecasts and assessments of drought to the American people.

Congress called on NIDIS to coordinate federal drought research, and to build upon existing federal, tribal, state, and local forecasting and assessment partnerships. NIDIS is led by the Climate Program Office of the National Oceanic and Atmospheric Administration (NOAA). The Public Law reauthorizing NIDIS in 2014 (P.L.113-86) further identifies the following goal of NIDIS, to "continue ongoing research and monitoring activities related to drought, including research activities relating to length, severity, and impacts of drought and the role of extreme weather events and climate variability in drought."

NIDIS was again reauthorized in 2019 (P.L. 115-423), calling on NIDIS to advance several additional priorities:

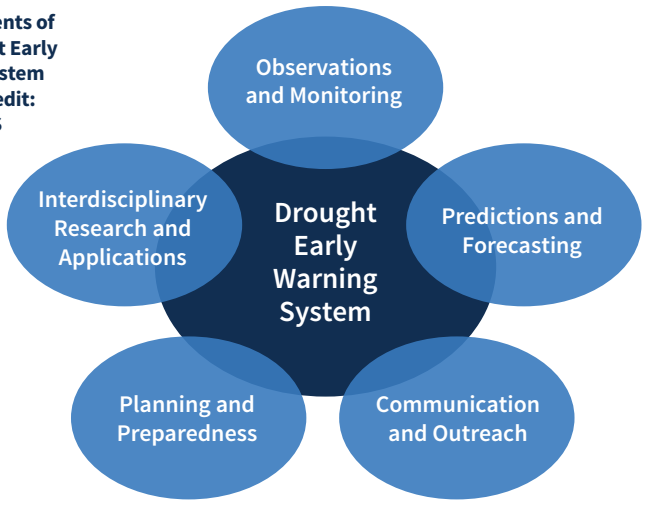
- Provide timely data, information, and products that reflect watershed differences in drought conditions
- Utilize existing forecasting and assessment programs and partnerships, including forecast communication coordinators and cooperative institutes, and improvements in seasonal and subseasonal precipitation and temperature and low flow water prediction
- Engage with the private sector to improve drought monitoring, forecast, and communication, if such partnerships are appropriate, cost-effective, and beneficial to the public and certain decision-makers
- Utilize and support monitoring by citizen scientists, including by developing best practices to facilitate maximum integration of data
- Develop a strategy for a national coordinated soil moisture monitoring network

NIDIS's goal is to improve the nation's capacity to manage drought-related risks by providing the best available information and tools to assess the potential impacts of drought, and to prepare for and mitigate the effects of drought. Toward that end, NIDIS seeks to create a Drought Early Warning System (DEWS) for all regions of the nation.

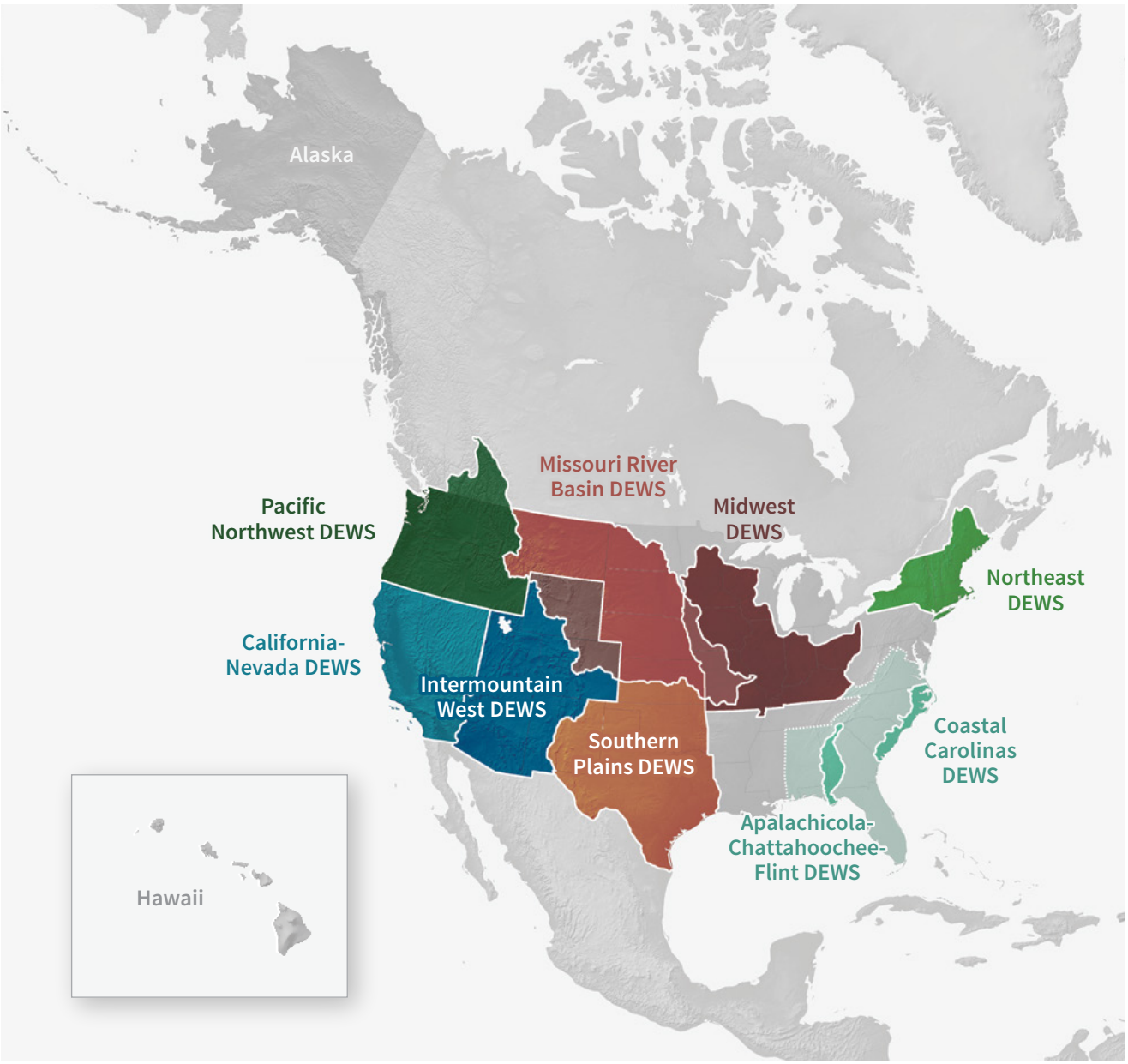
NIDIS Mission

NIDIS's mission is to improve the nation's capacity to proactively manage drought-related risks, by providing those affected with the best available information and resources to assess the potential for drought and to better prepare for, mitigate, and respond to the effects of drought.

Developing a nationally-consistent DEWS requires more than a one-size-fits-all solution. Drought in Maine looks different from drought in New Mexico. When seeking indicators of drought, a place that depends on snowpack for its annual water supply must monitor different factors compared to a place where liquid precipitation



▶ Components of the Drought Early Warning System (DEWS). Credit: NOAA NIDIS



▲ Map of regional Drought Early Warning Systems (DEWS). NIDIS will be launching a new Southeast DEWS (*dotted outline*) in 2020. Credit: NOAA NIDIS, Fiona Martin

determines the hydrology. Local economies, resources, and values influence how government, business, and the public respond to drought prediction, monitoring, and impacts. NIDIS's approach to building the foundation of a national DEWS has been to develop regional DEWS, where networks of researchers, academics, resource managers, policymakers, and other stakeholders share information and actions that help communities cope with drought.

WHAT IS A REGIONAL DEWS?

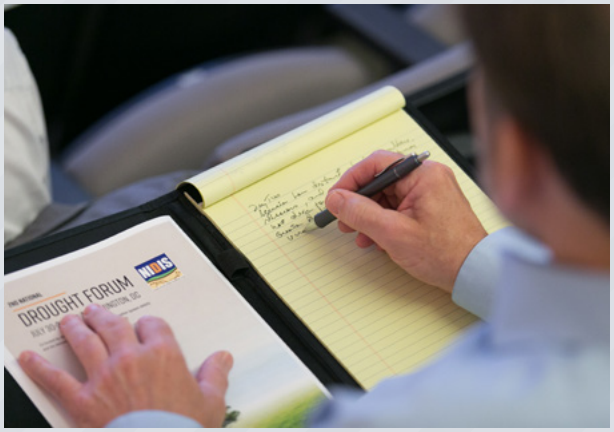
A regional DEWS utilizes new and existing partner networks to optimize the expertise of a wide range of federal, tribal, state, local, and academic partners in order to make climate and drought science and impact data readily available, easily understandable, and usable for decision makers. A regional DEWS also improves the capacity of stakeholders and economic sectors to better monitor, forecast, plan for, and cope with the impacts of drought at all spatial and time scales. □

National Drought Forum session on National Security and Drought, hosted by Sherri Goodman with the Wilson Center. Credit: NOAA NIDIS

NATIONAL DROUGHT FORUM

On July 30–31, 2019, the second National Drought Forum was held at the U.S. Institute of Peace in Washington, D.C.

The Forum was planned and coordinated by the National Integrated Drought Information System (NIDIS), a part of the National Oceanic and Atmospheric Administration (NOAA), along with the National Drought Resilience Partnership (NDRP). The Forum convened high-level drought experts and decision-makers from drought-impacted regions and economic sectors of the country, along with the private sector, research institutions, nonprofit organizations, global institutions, and officials across all levels of government to assess the status of national drought readiness, and to review progress made



▲ (*Top*) **Dr. Neil Jacobs, Assistant Secretary of Commerce for Environmental Observation and Prediction, speaks at the second National Drought Forum. (*Bottom left*) Note taking. (*Bottom right*) The forum provided valuable networking opportunities. Credit: NOAA NIDIS**

and determine new priority actions around drought early warning and long-term resilience issues.

The first National Drought Forum was held by NIDIS in December 2012, in large part to take stock of the 2012 drought across much of the Great Plains. Since 2012, several major drought events have impacted regions around the United States, including the multi-year California drought, the Northern Plains drought of 2017, a historic drought across New England and New York in 2016, and ongoing drought conditions throughout the Intermountain West region.

In the wake of the 2012 National Drought Forum and subsequent droughts, a number of programs and partnerships have launched or occurred to help predict and monitor drought, and to better understand and mitigate drought impacts, including:

- National Drought Resilience Partnership (2013)
- NIDIS Reauthorization (2014)
- Western Governors Association Drought Forum (2014)
- NOAA's National Water Center (2014)
- USDA Climate Hubs launched (2014)
- US Drought Monitor in Farm Bill Reauthorization (2014)
- Bureau of Reclamation's Drought Response Program (2014)
- State of California Sustainable Groundwater Management Act (2014)
- State of Nevada Drought Forum (2015)
- Drought Risk Management Research Center (2015)
- NASA Western Water Application Office (2016)
- Four new NIDIS Drought Early Warning Systems: Midwest, Pacific Northwest, Nevada, and Northeast (2016, 2017)
- USGS Integrated Drought Science Plan (2017)
- Colorado River Drought Contingency Plan (2019)
- NIDIS Reauthorization (2019)
- American Water Works Association's M60 Drought Preparedness and Response Manual (2019)
- $700M in WIFIA drought resilience loans (2019)

▲ NIDIS Director Veva Deheza speaks at the second National Drought Forum. Credit: NOAA NIDIS

These initiatives have resulted in earlier drought warning, better response and coordination across the Federal government and state governments, improved preparedness, and long-term drought resilience. Yet, challenges remain to address the persistent gaps and meet the needs of communities that continue to feel the impact of drought events. For example, significant advances in our observing, process understanding, and modeling capabilities are needed to improve drought prediction and information services.

A National Drought Forum Planning Committee was formed to assist in the Forum's steering and planning. In advance of the Forum, the Committee helped to shape the Forum's goals and objectives, agenda, identified speakers and participants, and helped prepare for the event.

The Forum's accomplishments included:

- Taking stock of lessons learned and progress towards U.S. drought readiness since the first Forum in 2012;
- Strengthening the state–federal relationship to realize greater collaboration and promote, where appropriate, cooperative partnerships with U.S. businesses to address drought across time scales and across levels of government and sectors;
- Featuring the Federal Water Officials and their 2019 priority actions for the National Drought Resilience Partnership
- Discussing new information and opportunities for coordination that help move the nation from a reactive to a proactive approach to drought risk management; and
- Producing a list of action items that could improve U.S. drought readiness and resilience.

Action Items were subsequently organized in several key areas:

- Advancing Applied Research and Process Understanding
- Strengthening Drought Monitoring and Observations
- Developing Decision-Support Tools
- Quantifying Drought Impacts
- Prioritizing Integrated Water Resource Management
- Mitigating Drought through Ecosystem Restoration
- Financing Pre-Disaster Drought Mitigation
- Communicating and Coordinating Drought Information □

RESEARCH & RESOURCES

This section features just some of the NIDIS research projects completed in 2019 as well as several decision-support resources that are in development or available now. Check out the section on the Drought Early Warning Systems (DEWS) to learn about many more NIDIS research projects and tools.

Water treatment plant at sunset. Credit: People Image Studio

REPORTS EXAMINE THE 2017 NORTHERN PLAINS FLASH DROUGHT

The 2017 Northern Plains drought sparked wildfires, destroyed livestock forage, and reduced agricultural production.

▲ Rails and private rangeland along Montana Hwy 81 near Denton, Fergus County, Montana. Credit: Kevin Hyde, Montana Climate Office

Neither the drought's swift onset nor its severity were forecasted. In May 2017, the region was mostly drought-free, and at least average summer precipitation was forecasted. By July 2017, North Dakota, South Dakota, eastern Montana, and the Canadian prairies were experiencing severe to extreme drought, resulting in fires that burned 4.8 million acres across both countries and U.S. agricultural losses in excess of $2.6 billion. NIDIS and partners have published two reports to examine the evolution and impacts of the drought, as well as lessons learned, needs, and gaps.

The report, *Flash Drought: Lessons Learned From the 2017 Drought Across the U.S. Northern Plains and Canadian Prairies*, examines the historic 2017 drought event and its impacts, identifies opportunities to improve timeliness of and accessibility to early warning information, and identifies applied research questions and opportunities to improve drought-related coordination and management within the Missouri River Basin Drought Early Warning System.

The needs that were repeatedly voiced during this study provide stepping stones to improve outcomes in future droughts for this and other regions, including:

- Invest in new and existing monitoring and observation networks, which would support the development of better indicators to provide early warning and allow decision-makers to better assess their drought risk and determine what actions to implement.
- Improve the understanding of the relevant processes that inform forecast models in the region, which could improve seasonal forecasts to enhance drought preparedness.
- Improve drought mitigation and response plans to consider trade-offs and actions that benefit both the human and ecosystem health and services, and put plans in place before a drought hits.
- Maintain strong relationships and networks to share information between federal, state/provincial, tribal, and local stakeholders before, during, and after drought, thereby improving the process of drought preparedness and response.

The report, *The Causes, Predictability, and Historical*

◀ NIDIS and partners published two reports to examine the evolution and impacts of drought, as well as lessons learned, needs, and gaps. Credit: NOAA NIDIS.

Context of the 2017 U.S. Northern Great Plains Drought, evaluates the causes, predictability, and historical context of the 2017 Northern Plains drought. The study was led by a team of weather and climate experts from NOAA's Earth System Research Laboratory's Physical Sciences Division and the Cooperative Institute for Research in Environmental Sciences located at the University of Colorado Boulder.

This study demonstrated that the rapid onset of the drought in the spring and summer of 2017 was mainly due to failed rains. Observed May–July precipitation over eastern Montana was the lowest on record and average precipitation over Montana, North Dakota, and South Dakota was the third lowest on record dating back to at least 1895. Failed rains led to the third largest soil moisture decline for any three-week period over eastern Montana since at least 1916. Climate model simulations reveal that droughts with intensity similar to that of 2017 are now 20% more likely due to anthropogenic influences. Anthropogenic influences increase the likelihood of droughts in July because of long-term reductions in soil moisture, also known as aridification. Aridification is forced by increases in evapotranspiration associated with rising temperatures. Below average May–July 2017 precipitation was not predicted in advance of the season. Cumulative precipitation deficits were only predictable through sequences of up to three day forecasts. Sequences of longer than five day forecasts provided no indication that the seasonal evolution of precipitation would be different from average.

NOAA/NIDIS is incorporating this research into the development of a working strategy on flash drought. In 2020, this will include work towards a shared definition of flash drought and identification of research needs, with an emphasis on early warning and applications. □

Soil moisture is important for agricultural monitoring, weather prediction, and drought and flood forecasting. Credit: Valentina Morgun

NATIONAL COORDINATED SOIL MOISTURE MONITORING NETWORK

Soil moisture is a critical land surface parameter affecting a wide variety of economically and environmentally important processes.

From agricultural monitoring, to weather prediction, to drought and flood forecasting, the value of soil moisture status is undeniable. At the same time, the means and methods of monitoring soil moisture are undergoing rapid growth and evolution with the advent of new in situ and proximal sensors, new data telemetry methods, and new remote sensing technologies to provide broad and accurate soil moisture estimates.

The United States has a prolific but uncoordinated collection of soil moisture monitoring networks at the national, state, and local levels. The absence of a coherent strategy leads to a host of problems including many states lacking adequate monitoring, multiple data sets which are not standardized or directly comparable, and no clear plan for how best to target investments to improve the monitoring infrastructure. Because of these deficiencies, the United States has not yet capitalized on the transformative potential of nationwide, coordinated in situ soil moisture monitoring and reporting.

In response to this need, and in accordance with the 2019 NIDIS reauthorization, NIDIS, USDA, and other partners are developing a strategy for the National Coordinated Soil Moisture Monitoring Network (NCSMMN) to integrate soil moisture data from over 1,800 stations with remotely-sensed and modeled data for the generation of real-time, easy-to-understand products. These products are intended to help reduce risks from hazards such as drought, flood, and fire, contribute to better hazard early warning systems, improve characterization of water

▲ **Corn suffering from drought. Credit: Kent Weakley**

budgets and climate models, improve crop production and resilience, and benefit many additional users.

The work of the NCSMMN will leverage, collaborate with, and support existing federal, tribal, state, multistate, and local monitoring efforts for soil moisture. The point-based (i.e., in situ) soil moisture data will be enhanced by aggregating the datasets into one place, and by creating end products that add value by, for example, visually showing the current spatial status of soil moisture across the United States. The NCSMMN will also support efforts to develop standardized and consistent metadata for monitoring networks, including sampling and characterization of soil physical properties relevant for U.S. Drought Monitor updates.

In addition, the NCSMMN effort will explore the best way to merge the in situ soil moisture data with remotely-sensed and modeled soil moisture products in order to create real-time, high-resolution, gridded national soil moisture maps and other useful products and services. The NCSMMN does not replace existing monitoring programs; rather, it is focused on coordinating and improving the status of soil moisture monitoring efforts both regionally and nationally.

To advance the NCSMMN, NIDIS and its partners undertook several key activities in 2019. A National Soil Moisture Workshop was held in May 2019 in Manhattan, KS on "Expanding the Frontiers of Soil Moisture Measurements and Applications." The workshop provided an opportunity for leaders in soil moisture research and development to come together in an interactive format to exchange ideas and develop collaborations. One of the primary goals of the workshop was to stimulate progress towards realizing the vision of the NCSMMN. With input from the workshop and through other collaboration, NIDIS and its partners developed a formal NCSMMN Strategy report that identifies a roadmap forward and resources needed for implementing a coordinated network. NIDIS capped the year by hiring a NCSMMN Program Specialist to coordinate and implement the cross-agency strategy.

The strategy document, *A Strategy for the National Coordinated Soil Moisture Monitoring Network: Coordinated, High-Quality, Nationwide, Soil Moisture Information for the Public Good*, was finalized in early 2020. This report will be a guiding document for the establishment of the NCSMMN. □

FIRO: OVERCOMING BARRIERS & REALIZING BENEFITS

Forecast-Informed Reservoir Operations (FIRO) use enhanced monitoring and improved weather and water forecasts to inform decision making to selectively retain or release water from reservoirs to optimize water supply reliability and environmental co-benefits and to enhance flood risk reduction.

NIDIS supported a workshop in September 2019 in Arlington, Texas to bring reservoir operators, water suppliers, and state agencies in the Southern Plains together with forecast providers, including NOAA, to examine opportunities and obstacles to the use of forecasts in reservoir operations. The workshop was organized by the Texas Water Development Board and the University of Texas at Arlington at the request of the states of Texas and Oklahoma. The workshop provided an opportunity for dialog between reservoir operators, water suppliers, state water agencies, and producers of seasonal and subseasonal forecasts and forecast products. Benefits, barriers, and future outlooks for Forecast-Informed Reservoir Operations (FIRO) were discussed.

BENEFITS OF FIRO

FIRO can help mitigate drought events:

- The events at Lake Mendocino from 2012–2104 became the trigger for FIRO there. Atmospheric Rivers (ARs) led to high reservoir levels and the standard process of releasing water was achieved. But what followed next was a drought that dropped reservoir levels to historic lows. Using forecasts to predict the drought could have prevented the extreme drop in

▲ **Scenic view of Lake Meredith National Recreation Area in Texas Credit: Traveller70**

water supplies. — *Marty Ralph, University of California, San Diego/Scripps Institution of Oceanography*

- Forecasts allow Brazos River Authority (BRA) in Texas to manage water supply by incorporating rainfall runoff and hydropower releases to help BRA determine the timing for initiating or discontinuing water supply releases. The Palmer Hydrological Drought Index has been incorporated into drought contingency as an early warning trigger and in the state approved water management plan/water accounting plan. — *Aaron Abel, Brazos River Authority*

FIRO can help mitigate extreme flood events:

- Tennessee Valley Authority (TVA) averted over $1.6 billion in flood damages in February 2019 through forecasting. For TVA, better forecasts equal lives and money saved. — *Tom Zimmerman, TVA*
- The City of Houston will be implementing FIRO in response to Hurricane Harvey and other recent flood events, with the goal of pre-releasing water from Lake Houston if predicted rainfall is 3 inches or greater in the Lake Houston watershed within a 48-hour forecasted period. — *Drew Molly, City of Houston*

BARRIERS TO FIRO

Workshop attendees discussed the need to improve the accuracy of subseasonal to seasonal (S2S) forecasting, both temporally and spatially. The following additional barriers or challenges were presented in applying FIRO:

- Lack of awareness and easy access to forecasts and models
- Prescriptive operations—can't or won't deviate from the previous plan
- People intimidated to use the available forecasts and models
- Lack of available system models
- Limited tools for real time management
- Ability to store or process data
- Demonstrating value to management
- Social and environmental pressures
- Politics
- Need for local advocates and support
- Personal interests
- Optimality
- Preferences required when tradeoffs are present

— *Jonathan Quebbeman, RTI International*

FUTURE OUTLOOK

The Southern Great Plains is a region of persistent drought interrupted by extreme rainfall events and flooding. Based on the presentations and lively discussions during the workshop, initial indications suggest that the application of the FIRO approach in the Southern Great Plains region represents an opportunity to augment water supply reliability in reservoir systems built and operated to manage flood control as well as an opportunity to augment flood protection in water supply reservoir systems built and operated to mitigate drought impacts. □

CSI: A NEW TOOL FOR COASTAL MANAGERS

Coastal drought is unique in its effects on the salinity dynamics of creeks, rivers, and estuaries.

▲ Photos of estuary near Wilmington, NC. Credit: Kirsten Lackstrom

Commonly-used drought indices characterize hydrological, agricultural, and meteorological conditions; however they do not incorporate salinity, a key stressor associated with coastal drought. Salinity is a critical response variable that integrates hydrologic and coastal dynamics including sea level, tides, winds, precipitation, streamflow, and tropical storms.

In response to this need, a Coastal Salinity Index (CSI) was developed to characterize coastal drought, monitor changing salinity conditions, and improve our understanding of the effects of changing salinities on fresh and saltwater ecosystems, fish habitat, and freshwater availability, providing economic, human health, and environmental benefits.

WHAT IS THE COASTAL SALINITY INDEX?

The motivation for a CSI came from the NIDIS Drought Early Warning System (DEWS) program for coastal North Carolina and South Carolina. The Coastal Salinity Index project has been supported by NIDIS, NOAA, the Carolinas Integrated Sciences and Assessments (CISA) program, a NOAA RISA, and the U.S. Geological Survey.

The CSI is a drought index tool that uses salinity data to characterize saline (drought) and freshwater (wet) conditions in coastal surface waters.

- The CSI uses an approach similar to the Standardized Precipitation Index (SPI) to show the probability of recording a given amount of salinity.
- The CSI can be computed for multiple time intervals from 1 to 24 months to characterize short- and long-term conditions.
- The CSI does not depict hourly to daily salinity fluctuations, but the response to monthly (and longer) precipitation and streamflow conditions.

WHO CAN USE THE CSI?

- **Resource managers:** those who monitor drought conditions in order to make decisions and manage resources, such as water, fisheries, wildlife, refuges, preserves, and forests.
- **The drought monitoring community:** those who monitor drought conditions, make determinations regarding drought status, and disseminate drought information, for example, drought coordinators

and response committees, State climatologists, and National Weather Service offices.

- **Researchers:** those who are interested in studying drought and improving understanding of the drivers and effects of drought in coastal areas.

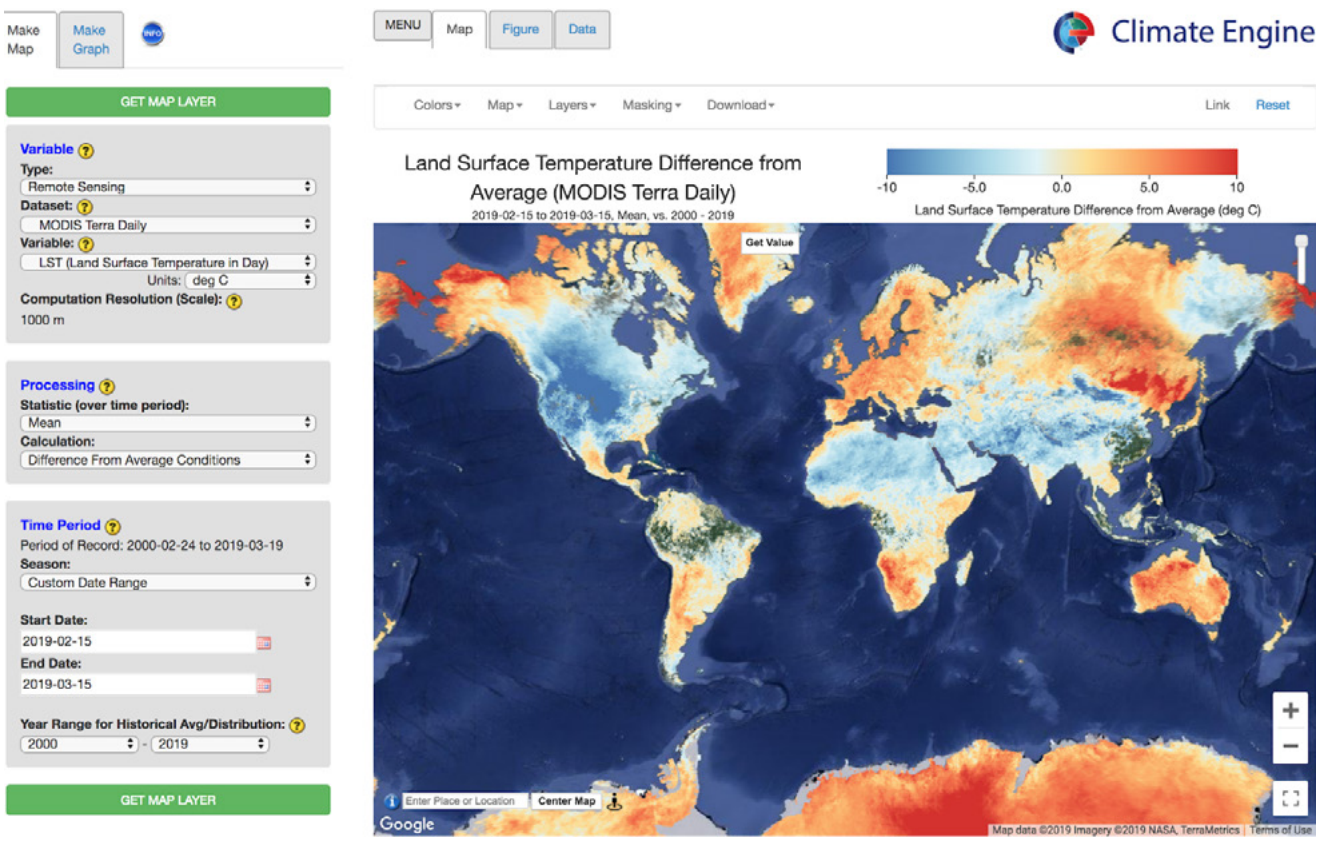
WHAT INFORMATION DOES THIS NEW TOOL PROVIDE?

This free, online tool has many functions including:

- Data and graphs for weekly trends for salinity and water temperature conditions, as an indicator of recent hydrological conditions.
- Data and graphs for monthly salinity averages.
- Downloadable software package (R-package), to encourage the use of CSI in current and future research efforts
- Access to real-time CSIs for the Carolinas
- A CSI User Guide

WHAT ARE THE FUTURE PLANS FOR THE CSI?

- **Increase number and spatial coverage of monitoring sites.** Include more real-time gauge stations along the Eastern seaboard and the Gulf of Mexico, with potential expansion to the Pacific coast.
- **Advance key research questions.** Better understand how salinity information can be incorporated into short and long-term planning in areas such as fisheries (e.g., oysters, crabs), conservation (e.g., wetlands) and water (e.g., municipal utilities) management.
- **Expand use of CSI applications in coastal decision making.** Develop more case studies of how the CSI can be utilized or improved.
- **Move towards predictive capacity. T**he CSI currently serves as an indicator of historical change and current conditions. Can the CSI evolve into a forecast tool as well? □



CLIMATE ENGINE: ON-DEMAND CLOUD COMPUTING & DATA VISUALIZATION

In an era of an increasing wealth of earth observations, approaches for quickly accessing, analyzing, and visualizing these environmental data to better inform decision making at relevant scales is lacking.

Specifically, there is a need to quickly process and visualize data to improve monitoring and early warning of drought (including snow drought), groundwater dependent ecosystems, fire danger, and crop failure risk. In response, the Desert Research Institute and University of Idaho, with support from NIDIS since 2016 and in partnership with Google and other federal partners, have developed ClimateEngine.org — an innovative web application that enables users to quickly process and visualize satellite earth observations and gridded weather data for environmental monitoring.

Climate Engine, a valuable example of a public–private partnership, is an "on-demand" cloud computing and visualization of climate and remote sensing data resource. Climate Engine enables users to analyze and interact with climate and land surface environmental monitoring datasets in real time. In addition to providing early warning, Climate Engine can help improve decision making related to water sustainability, water efficiency, agricultural productivity, and ecological health.

Utilizing access to one petabyte (1,000 terabytes) of cloud storage and 50 million donated hours of computing time

◀ (*Previous page*) **Dashboard showing land surface temperature difference. Credit: Climate Engine, Desert Research Institute and University of Idaho**

on Google's Earth Engine environmental cloud computing platform, the web-based application is able to mine, process, and analyze a 30-year archive of high resolution optical and thermal images taken of Earth by the Landsat satellites in a matter of seconds compared to hours and even days with traditional computing systems.

Climate Engine provides:

- Unprecedented access in visualizing and interacting with earth observation datasets
- Methods to compute big data for use in real-time monitoring or in a research context
- Access to simply download or share results instead of processing entire data archives locally
- Fully customizable spatial and temporal analyses
- Comprehensive set of variables that provide early warning indicators of climate impacts such as drought, wildfire, ecological stress, and agricultural production

In 2019, NIDIS supported two Climate Engine training sessions: one in April 2019 with the Navajo Nation and the other in October 2019 in Reno, NV with the Nevada Bureau of Land Management (BLM). The purpose of the trainings, which built on a 'roadshow' of Nevada BLM trainings in 2018, was to empower decision makers to use the tool for decision support related to drought, water use, agriculture, wildfire, and ecology including local scale information for assessing field scale impacts—such as vegetative drought (short-term soil moisture deficits) and hydrologic drought (long-term water deficits and low river flows).

The BLM Nevada office uses Climate Engine maps to better understand how vegetation greenness pairs with precipitation levels. For example, if an area has received ample precipitation but the vegetation is stressed, the cause isn't lack of precipitation; it could be overgrazing by livestock. Climate Engine maps and time series are also providing BLM staff new place-based information for assessing grazing permits.

▶ **Participants in Climate Engine NASA-DRI Navajo Nation Workshop.**

In a recent Nevada State Engineer's Office *water right ruling*, consultants used Climate Engine vegetation greenness maps to show that someone who wanted to expand their irrigated acreage hadn't actually watered their lands at all over a five-year period—and therefore, should forfeit their water rights. The State Engineer's Office agreed based on the clear results from Climate Engine and clearly defined law regarding forfeiture after five years of non-use.

NIDIS is continuing to support the advancement of Climate Engine including exploring the future of cloud computing and data storage for drought decision making and for utilization on *drought.gov*. □

DROUGHT & HUMAN HEALTH

Over the last century, droughts have caused more deaths internationally than any other weather-related disaster. Droughts in the United States, however, are not generally thought of as public health threats.

▲ A doctor examines a child. Credit: Cathy Yeulet

The often slow onset of drought, compared to other extreme events, makes it difficult to identify direct linkages between drought and societal impacts, as well as impacts that occur after a drought has ended. However, recent extreme droughts in the United States have caused significant human health outcomes, including decreased water quantity and quality, coccidioidomycosis (Valley fever) outbreaks in the southwestern U.S., increased mortality rates attributed to drought, and pernicious mental health outcomes as livelihoods are challenged.

By understanding linkages between droughts and human health, we can proactively warn and prepare our public health agencies for the health impacts associated with droughts, which, in turn, can reduce health risks and save lives. To address this need, NIDIS has developed a plan to develop a Drought and Public Health Strategy. The initial steps in this plan included holding with our partners a series of regional drought and public health workshops and a National Drought and Public Health Summit in 2019. Additional regional workshops will also be held in 2020. The Drought and Public Health strategy will be developed by the end of 2020.

The first regional workshop was held in February 2019 in Sacramento, CA with the California Department of Public Health, the Centers for Disease Control and Prevention (CDC), and the National Drought Mitigation Center (NDMC). The second regional workshop was held in November 2019 in St. Paul, MN with the Minnesota Department of Health and the University of Nebraska Medical Center (UNMC).

The National Drought and Public Health Summit, held in June 2019 in Atlanta, GA, brought together a diverse set of stakeholders for a discussion around the linkages between droughts and human health. Dr. Jesse Bell with the UNMC College of Public Health and summit co-host, opened with a discussion on the disconnect in our current understanding of the relationship between drought and public health. Bell noted that although steps can be taken to prevent negative health outcomes associated with drought, existing surveillance is not designed to identify health outcomes when drought actually occurs.

Many of the presentations that followed discussed known or potential human health outcomes related to drought, including:

◀ (*Left*) Preparing for the Health Effects of Drought: A Workshop for Public Health Professionals and Partners. February 4, 2019, in Sacramento, CA. (*Right, top and bottom*) Human Health California Workshop. Credit: NOAA NIDIS

- Droughts increase the probability of high arsenic concentrations in private wells and population exposed to arsenic across the contiguous U.S. *—Melissa Lombard, USGS*
- A 2017 study found a 1.55% increase in mortality from high severity worsening drought. *—Jesse Berman, University of Minnesota*
- There is a relationship between drought and wildfire episodes and an association between wildfire smoke and adverse health outcomes. *—Ambarish Vaidyanathan, CDC*
- The frequency of dust storms, often associated with drought, more than doubled from the 1990s and 2000s in the Southwest. Rising dust can cause negative effects on human health, such as increased traffic accidents and Valley Fever. *—Daniel Tong, George Mason University/NOAA*
- Drought accounted for 38% of West Nile virus cases in Nebraska between 2002–2018. *—Kelly Helm Smith, NDMC*
- Internationally, drought can lead to reduced food intake, lack of a varied diet, the spread of disease, and forced migration. *—Sally Edwards, Pan American Health Organization*

Another important topic discussed was what populations will most be affected by drought. Presenters identified populations at risk, both nationally and internationally, and ways to reach them.

In addition to the workshops, NIDIS has two ongoing projects with the UNMC College of Public Health. The project, "Determining the role soil moisture had on the 2017 Valley fever outbreak," is researching a recent outbreak of Coccidioidomycosis (also called Valley Fever) in the southwestern United States to help understand the factors that control incidence of the disease to help forecast and predict the next outbreak. The project, "Evaluation of Historical Drought-Related Mortality Events," will use national mortality multiple cause data that go from 1960–2015 to identify regional linkages of drought and health. □

Stay tuned in 2020 for results from the research projects and the release of the NIDIS Drought and Human Health Strategy.

Skier skiing downhill in high mountains. Credit: Lukas Gojda

DROUGHT & THE OUTDOOR INDUSTRY

The outdoor recreation industry is responsible for 2.2% of national GDP. However, projected increases in the frequency and severity of drought threatens the viability of water-based recreation businesses.

NIDIS co-hosted a seminar with the University of Colorado Boulder's Masters of the Environment Program (MENV) in November 2019 in Boulder, CO, to explore the effects of uncertain snowpack levels, streamflows, and warming temperatures on outdoor recreation businesses with a focus on snow- and water-based activities (skiing, fishing, rafting, etc.).

The seminar included presentations and discussion of new and novel research on drought impacts to the industry, drought information needs, and recommendations for future actions to strengthen drought resiliency of this key sector of the economy. The seminar was based in part on a year-long research project, "Drought Risks and Information Needs of the Outdoor Recreation Industry," sponsored by NIDIS in partnership with the MENV program. The project incorporated 47 interviews and 65 survey responses with outdoor industry stakeholders to investigate drought issues facing the outdoor recreation industry in the Intermountain West (Arizona, Colorado, New Mexico, Utah, and Wyoming).

Graduate students from the MENV program delivered the keynote presentation at the seminar. They began the presentation with a discussion on the socioeconomic impacts of drought on the outdoor recreation industry. The outdoor industry has many small businesses, and those are hit the hardest in drought. Businesses reported 20–50% reductions in annual revenue due to drought. In the outdoor recreation retail subsector, risk gets transferred from manufacturers to stores to employees, who may get laid off if sales go down. Furthermore,

◀ **Scenic ski lift chairs. Credit: Konoplytska.**

▲ **Rafting. Credit: Amateur007**

◀ **Men fishing in a river with fly rods. Credit: Lukas Gojda**

widespread mental health impacts were reported by small businesses due to the stress of drought.

Most businesses examined in the MENV/NIDIS study have found ways to adapt in order to partially mitigate the risk of negative drought impacts on their business. These include business diversification, marketing to attract customers and adjust expectations, purchasing adjustments, and snowmaking. Despite a number of adaptation strategies being available to the outdoor recreation industry, there are still barriers that make it difficult to impossible to adapt during drought events. Capacity was one of the key barriers identified, as diversifying requires additional resources. Customer expectations was another barrier mentioned. While an outfitter may be able to provide a different experience to a customer, sometimes customers have fixed expectations and are hesitant or unwilling to accept changes to their expected experience. Additional barriers included geographic location, distrust of forecasts, and lack of drought knowledge.

The information needs of the outdoor recreation industry was also a key focal point of the study. Outdoor recreation businesses with financial resources can access commercial forecasts. For others, there is universal demand for long-range forecasts on precipitation, streamflows, and temperatures. Many businesses also mentioned that current monitoring resources can be very complicated and difficult to navigate, and they're looking for a more user-friendly way to gather data about current conditions.

Recommendations from the study included a dashboard that consolidates popular forecasting resources. Since different subsectors in the industry reference different resources, having a specific dashboard for each of the subsectors would be most useful for business owners. In addition, NIDIS could form a working group with the outdoor recreation industry so that the industry can provide continuous feedback for how NIDIS can better support outdoor businesses and act as a conduit for NIDIS' information and services.

The seminar closed with the participants discussing NIDIS' priorities and next steps with regard to outdoor recreation. The full report from the NIDIS/MENV project will be published in 2020. □

Winter wheat on a Chippewa Cree Tribal Farm. Rocky Boy Reservation, Montana. Credit: USDA NRCS

TRIBAL ENGAGEMENT

NIDIS partnered with the University of Colorado Masters of Environment program in 2019 on a research project to improve collaboration with tribal nations in the Midwest and Missouri River Basin DEWS.

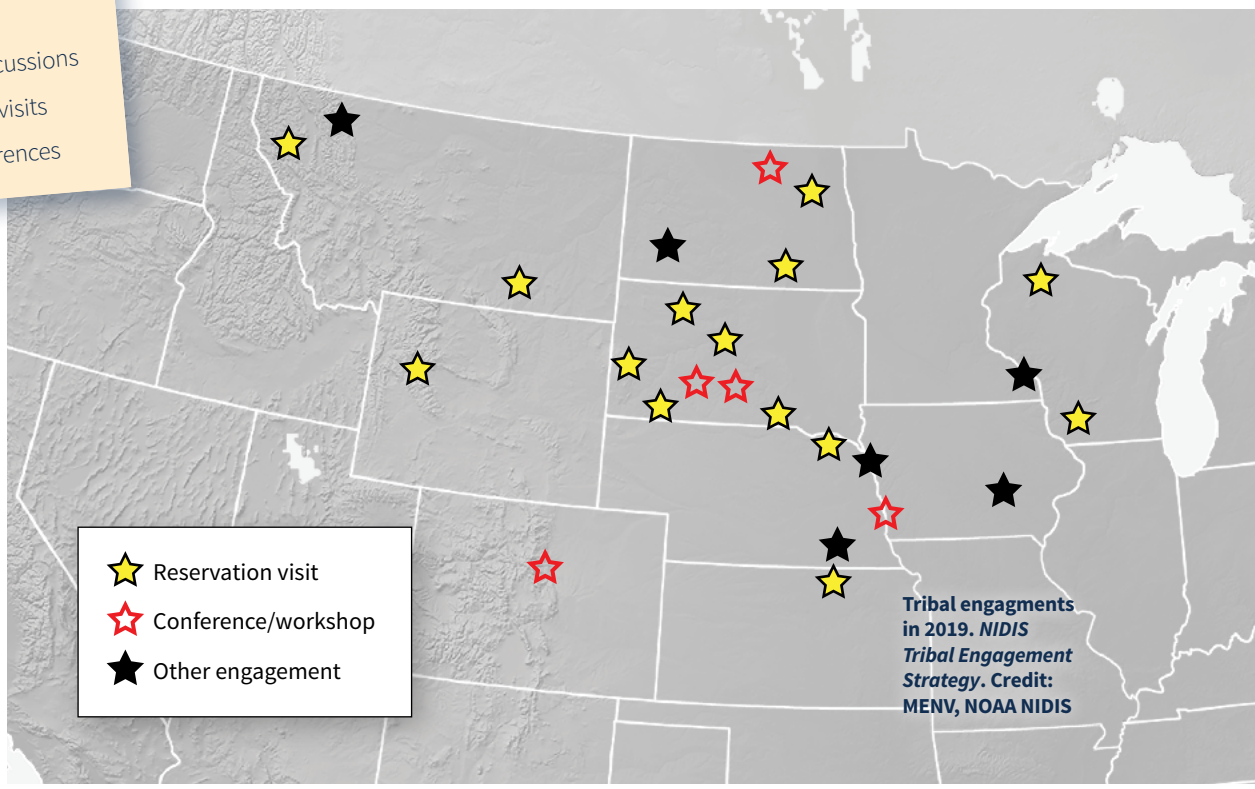
NIDIS partnered with the University of Colorado Masters of Environment (MENV) program in 2019 on a research project to improve collaboration with tribal nations in the Midwest and Missouri River Basin DEWS. The purpose of the project was to increase NIDIS' engagement with tribal resource managers through face-to-face contact, better understand the current status of drought knowledge and planning in tribal nations, map and identify key drought vulnerabilities and capacity gaps of tribal nations in both regions, and provide tribal nations with tailored drought information for their reservation.

Over the course of the year, the MENV team collected more than 100 key contacts, including more than 20 strong allies, had in-depth discussions with more than 50 tribal resource managers from 20 reservations, visited 15 reservations, and attended 12 tribal conferences and meetings. The information gathered, lessons learned, and key priorities moving forward are captured in a Tribal Engagement Strategy for NIDIS, which will be completed in 2020 and implemented thereafter.

NIDIS also participated in the 4th National Adaptation Forum, which took place in Madison, WI in April 2019. The Forum gathered the adaptation community to foster knowledge exchange, innovation, and support for practical climate adaptation solutions. NIDIS co-organized and moderated a session on "Utilizing Partnerships to Enhance Climate Monitoring and Drought Management on Tribal Lands". The tribal session provided a broad perspective on the planning process for drought, highlighting projects that have focused on several important pieces of

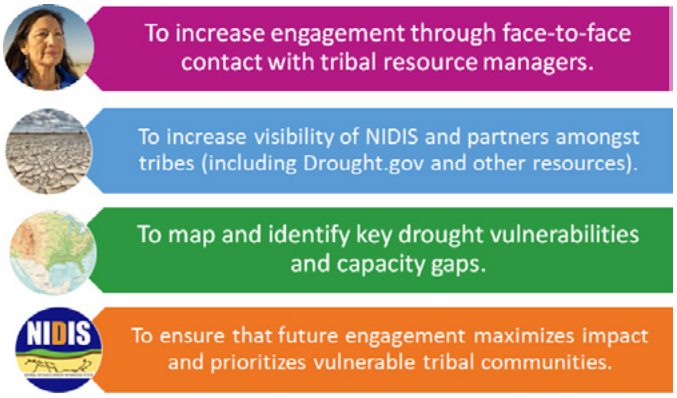
By the Numbers:

- ✓ **100+** Key contacts
- ✓ **20** Strong allies
- ✓ **50** In-depth discussions
- ✓ **15** Reservation visits
- ✓ **12** Tribal conferences



Tribal engagments in 2019. *NIDIS Tribal Engagement Strategy*. Credit: MENV, NOAA NIDIS

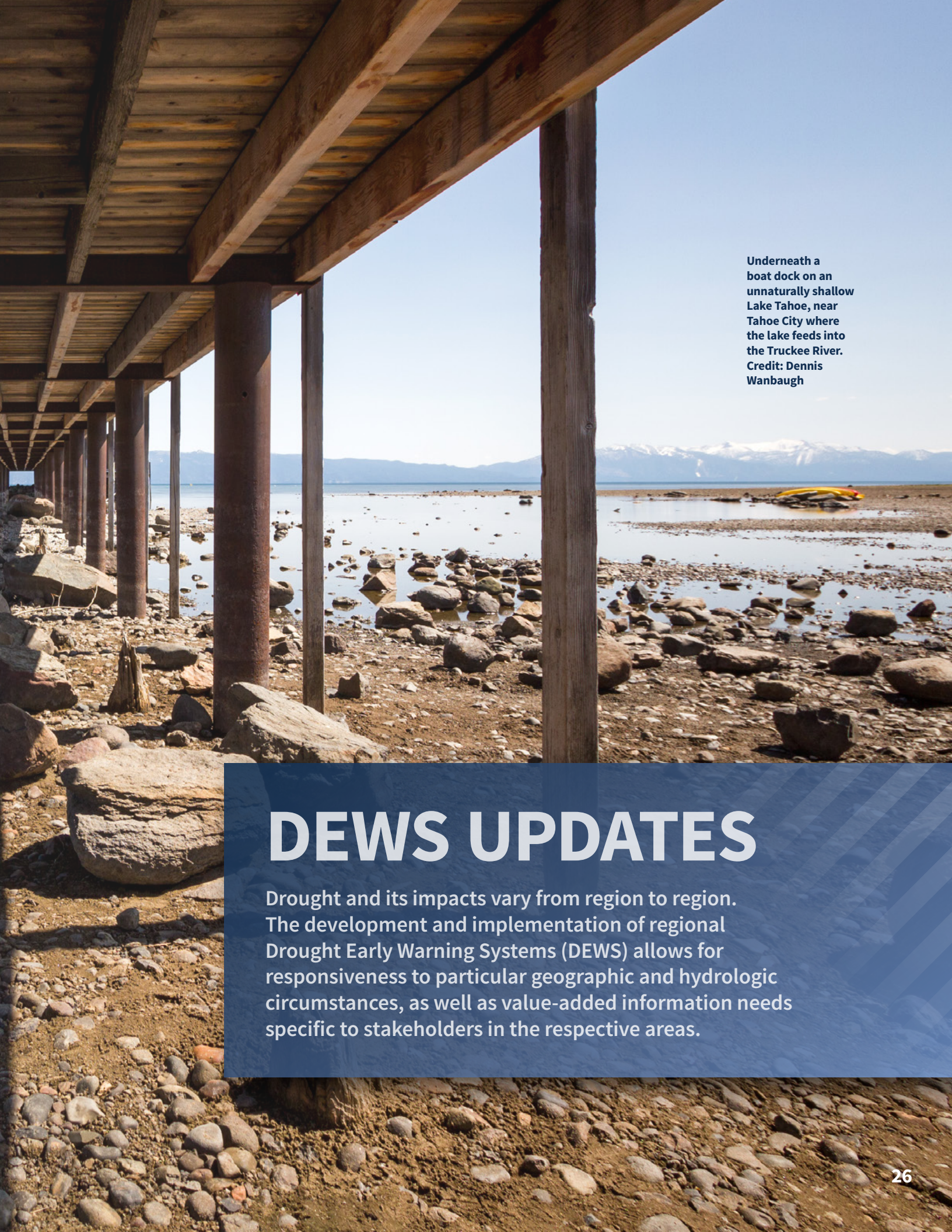
▲ The Blackfeet Nation buffalo herd in its summer pasture in Browning, Montana. Credit: Kelly Stoner, WCS



▲ Goals outlined in the *NIDIS Tribal Engagement Strategy*. Credit: MENV, NOAA NIDIS

that process including monitoring conditions, conducting vulnerabilities, and identifying culturally appropriate resilience actions to address these vulnerabilities.

Lastly, NIDIS provides matching funds for tribes applying to the Bureau of Indian Affairs Tribal Resilience and Ocean and Coastal Management Planning Grants. The NIDIS funds go towards tribal drought planning efforts. In 2019, this included a North Dakota and South Dakota Tribal Adaptation Planning Training and Workshop. □



Underneath a boat dock on an unnaturally shallow Lake Tahoe, near Tahoe City where the lake feeds into the Truckee River. Credit: Dennis Wanbaugh

DEWS UPDATES

Drought and its impacts vary from region to region. The development and implementation of regional Drought Early Warning Systems (DEWS) allows for responsiveness to particular geographic and hydrologic circumstances, as well as value-added information needs specific to stakeholders in the respective areas.

Chattahoochee River and Trees on a cloudy day. Credit: Curtis Cozier

ACF RIVER BASIN DEWS

The Apalachicola-Chattahoochee-Flint (ACF) River Basin covers over 12 million acres of watershed across Georgia, Alabama and Florida.

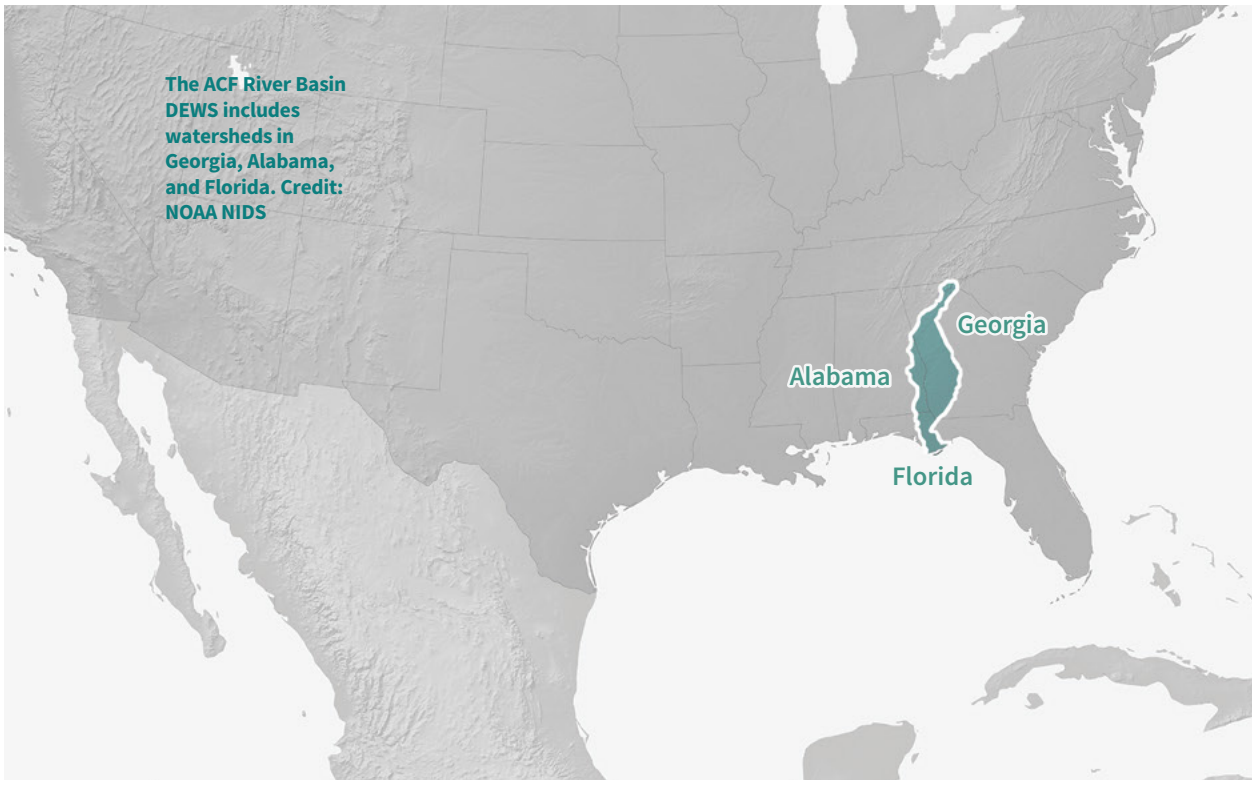
Water in the ACF Basin meets a range of needs, including, but not limited to, municipal and industrial water supply, agricultural irrigation, hydroelectric generation and thermoelectric cooling, and environmental and instream flows. Metropolitan Atlanta, with a population of more than 5 million, relies upon Lake Lanier and the Chattahoochee River for approximately 70% of its water supply.

INTERACTIVE TOOL FOR DROUGHT IN THE ACF

NIDIS and NCEI, in partnership with ACF Stakeholders (ACFS), is developing the ACF Drought Dashboard, a web-based application that allows users in the region to monitor drought situations in real-time and facilitate data-driven decision making. The ACF Drought Dashboard development began in 2019, and will be followed by a series of stakeholder listening sessions in 2020 to seek input on drought information needs and interface design. The Drought Dashboard will be located on the U.S. Drought Portal (Drought.gov). Information will be relevant to the broader Alabama/Florida/Georgia region, and could be expanded to additional geographic regions in the future.

IMPROVED REGIONAL COMMUNICATION DURING 2019 FLASH DROUGHT

In response to a rapidly developing drought in the Southeast, NIDIS organized two Southeast Drought Update webinars to improve regional information sharing on the flash drought. Topics included an overview of the drought, causes, outlooks and impacts, with a focus on impacts to agriculture and reservoir levels. NIDIS coordinated these webinars with the National Weather



The ACF River Basin DEWS includes watersheds in Georgia, Alabama, and Florida. Credit: NOAA NIDS

◀ Peanut on dry land. Credit: Stephen Tjipto Hartono

▶ Southeast Drought Update Webinar. Credit: NOAA NIDIS

Service (NWS), the Southeast Regional Climate Center, and other regional partners.

ACF WEBINARS

ACF River Basin Drought Assessment Webinars were held monthly throughout 2019. These webinars provided the region's stakeholders with timely information on current and developing drought and flood conditions. They were led by the Auburn University Water Resources Center with support from NIDIS. Presentations were provided by the Florida Climate Center, ADECA Office of Water Resources, USGS South Atlantic Water Science Center, NWS Southeast River Forecast Center, and US Army Corps of Engineers Mobile District. □

In 2020, the ACF River Basin and Coastal Carolinas will be incorporated into Southeast DEWS. The Southeast DEWS will include Alabama, Georgia, Florida, South Carolina, North Carolina, and Virginia.

North Carolina Outer Banks Bodie Island lighthouse and marsh boardwalk. Credit: Mark VanDyke

COASTAL CAROLINAS DEWS

North Carolina and South Carolina experience considerable climate variability, including drought, heavy precipitation, tropical storms, ice storms, and severe heat.

This region experienced significant events in 1998–2002, 2007–2009, and 2010–2013. These events exposed existing and emerging drought vulnerabilities that are particular to coastal regions. These include impacts associated with changes to water quality conditions, such as increasing salinity levels, and the availability and timing of freshwater to support estuarine and coastal ecosystems and economies.

NEW COASTAL SALINITY INDEX TOOL

The Coastal Salinity Index (CSI) was developed to characterize coastal drought, monitor changing salinity conditions, and improve understanding of the effects of changing salinities on fresh and saltwater ecosystems, fisheries, and freshwater availability for municipal and industrial use. The CSI currently covers the coasts of North Carolina, South Carolina, and Georgia, and serves as a blueprint for other U.S. coastal areas. This project was funded by NIDIS, with support from the U.S. Geological Survey and the Carolinas Integrated Sciences and Assessments (CISA, a NOAA RISA team) program.

SUPPORTING CITIZEN SCIENCE CONDITION MONITORING

Condition Monitoring reports provide a tool for Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) volunteers to submit regular weekly reports describing recent weather conditions and their impacts on the local environment. CoCoRaHS is a citizen science network launched in 1998. With funding from NIDIS, a Condition Monitoring report tool was developed by CISA (a NOAA RISA team) as a pilot under the Coastal Carolinas DEWS. This successful regional effort was expanded to a national scale in 2016. In 2019, regional guidance for CoCoRaHS volunteers was developed and released.

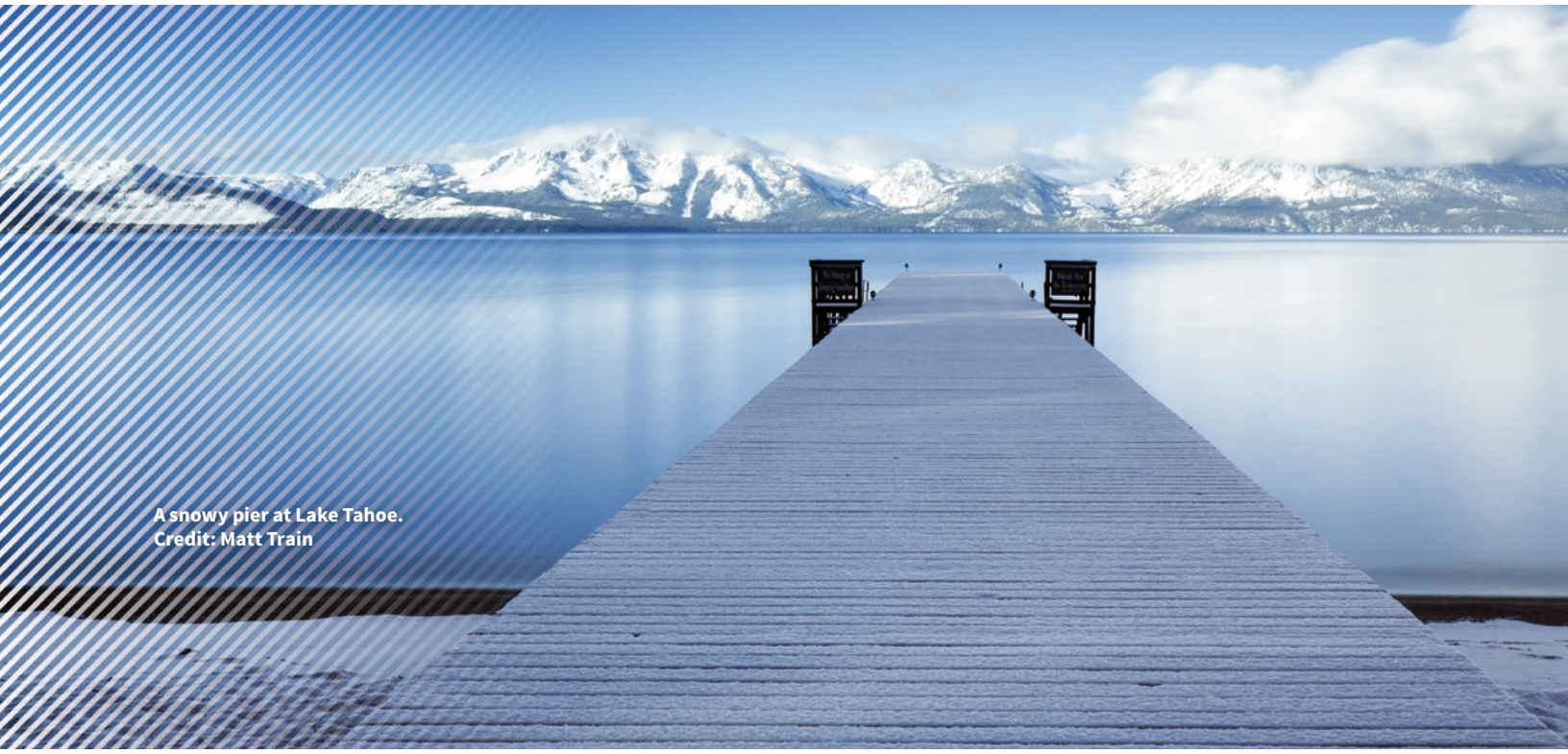
MITIGATING COASTAL ZONE FIRE RISK WITH A SOIL MOISTURE MONITORING NETWORK

In 2019, The State Climate Office of North Carolina, with funding from NIDIS and support from CISA (a NOAA RISA team), established a system of organic soil moisture monitoring stations at select locations in eastern North Carolina. Real-time information from this network will address needs regarding coastal zone fire risk. Key partners included the North Carolina Forest Service, The Nature Conservancy, North Carolina State Parks, and U.S. Fish & Wildlife Service. □

▶ **Estuary near Wilmington, NC. Credit: Kirsten Lackstrom**

In 2020, the ACF River Basin and Coastal Carolinas will be incorporated into Southeast DEWS. The Southeast DEWS will include Alabama, Georgia, Florida, South Carolina, North Carolina, and Virginia.

▶ **Wildfire in Great Dismal Swamp National Wildlife Refuge, Virginia. Credit: Mike Petruncio, North Carolina Forest Service**



A snowy pier at Lake Tahoe.
Credit: Matt Train

CALIFORNIA-NEVADA DEWS

Drought in California and Nevada is a common occurrence that can last for multiple years.

The regional climate is characterized by a distinct dry season (approximately May to September) and wet season (October–April) defined by a few large precipitation events. Topography within the CA-NV region creates a diverse set of climate conditions, from the snowy peaks of the Sierra Nevada Range to the Mojave Desert, to the mountains and valleys of the Basin and Range. Given the extreme variability, both spatially and temporally, efficiently using and effectively managing finite water resources is a high priority.

IMPROVING FIRE RISK MANAGEMENT WITH DROUGHT EARLY WARNING INFORMATION

NIDIS supported research, published in 2019 by the Western Regional Climate Center (WRCC) and the Desert Research Institute (DRI), examined the relationships in CA-NV between common drought indices and National Fire Danger Rating System (NFDRS) outputs to help understand what drought indices might complement or be integrated into NFDRS. Results show a combination of drought indices is needed when looking at subregions of California and Nevada. However, drought indices that incorporate both evaporative demand and flexible time scales have the most promise to help improve seasonal fire potential outlooks. The research was funded by NIDIS through NOAA Climate Program Office's Sectoral Applications Research Program (SARP).

CA-NV DEWS REGIONAL PARTNER MEETING

Forty federal, tribal, state, local, academic, private sector, and non-governmental partners gathered over two days in Sacramento, CA in November 2019 to discuss current and future drought activities, identify 3-year strategic priorities for the DEWS network, and learn about innovative drought data information and resources in California-Nevada. Outcomes will be integrated into the CA-NV DEWS Strategic Action Plan, to be released in 2020.

HEALTH EFFECTS OF DROUGHT WORKSHOP

Recent droughts in California have illuminated the

The CA-NV DEWS includes all of California and Nevada. Credit: NOAA NIDIS

▲ California-Nevada Drought and Climate Outlook Webinar. Credit: NOAA NIDIS

impacts on health, including those associated with decreased water quantity and quality, coccidioidomycosis (Valley fever) outbreaks, increased mortality rates, and adverse mental health outcomes. On February 4, 2019, the California Department of Public Health (CDPH), NIDIS, the Centers for Disease Control and Prevention (CDC), and the National Drought Mitigation Center (NDMC) co-hosted a workshop on Preparing for the Health Effects of Drought. The results of this workshop, along with those of six other regional drought and human health workshops and a National Summit, will inform a Drought and Human Health Strategy for NIDIS in 2021 and beyond.

CALIFORNIA-NEVADA DEWS WEBINARS

The California-Nevada DEWS Drought & Climate Outlook webinars were held every other month throughout 2019. These webinars provided the region's stakeholders with timely information on current and developing drought conditions as well as climatic events like El Niño and La Niña. The webinars also discussed the impacts of these conditions on wildfires, floods, water supplies, and ecosystems, as well as impacts to industries like agriculture, tourism, and public health. The webinars were sponsored by NIDIS, the California Nevada Applications Program (a NOAA RISA team), WRCC, DRI, and Scripps Institution of Oceanography.

ONGOING PROJECT TO IMPROVE EARLY WARNING

The California Nevada Applications Program (CNAP), NIDIS, and fire personnel have assessed the Red Flag Warning (RFW) definition, inputs, usefulness, usability, and impact. This assessment has led to an ongoing project with the NWS to enhance the Red Flag Warning (RFW) matrix, which will be vetted in CA-NV.

NIDIS, through its support of CNAP, is partnering with USGS on groundwater research that will help CA implement the Sustainable Groundwater Management Act (SGMA). The research established an approach to estimate diversions and groundwater pumping in the Central Valley and is now supporting the development of an online decision support tool.

The Evaporative Demand Drought Index (EDDI) has been used as a drought indicator. Now, NIDIS and WRCC are working to make EDDI a forecasting tool for the first time. EDDI is being tested with subseasonal forecasts (1–30 days) of evaporative demand. □

Colorado River from Nankoweap Granaries in Grand Canyon. Credit: Beth Ruggiero-York

INTERMOUNTAIN WEST DEWS

While all five states in the Intermountain West depend on the over-allocated Colorado River, climatic, geographic, economic, and social conditions vary significantly across the region, which ranges from deserts and riparian woodlands to high valleys and alpine systems.

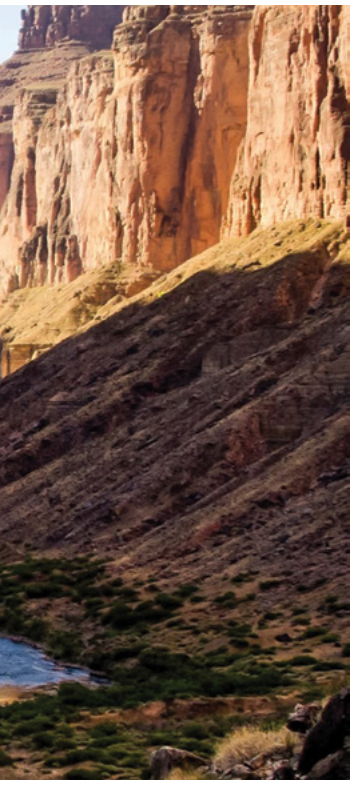
The Southwestern Monsoon is a dominant driver of weather in the Lower Basin states, while continental weather systems have a greater impact in the Upper Basin states. Droughts may onset quickly as a flash drought in portions of Colorado and Wyoming, and may last decades, as with current conditions in parts of Arizona.

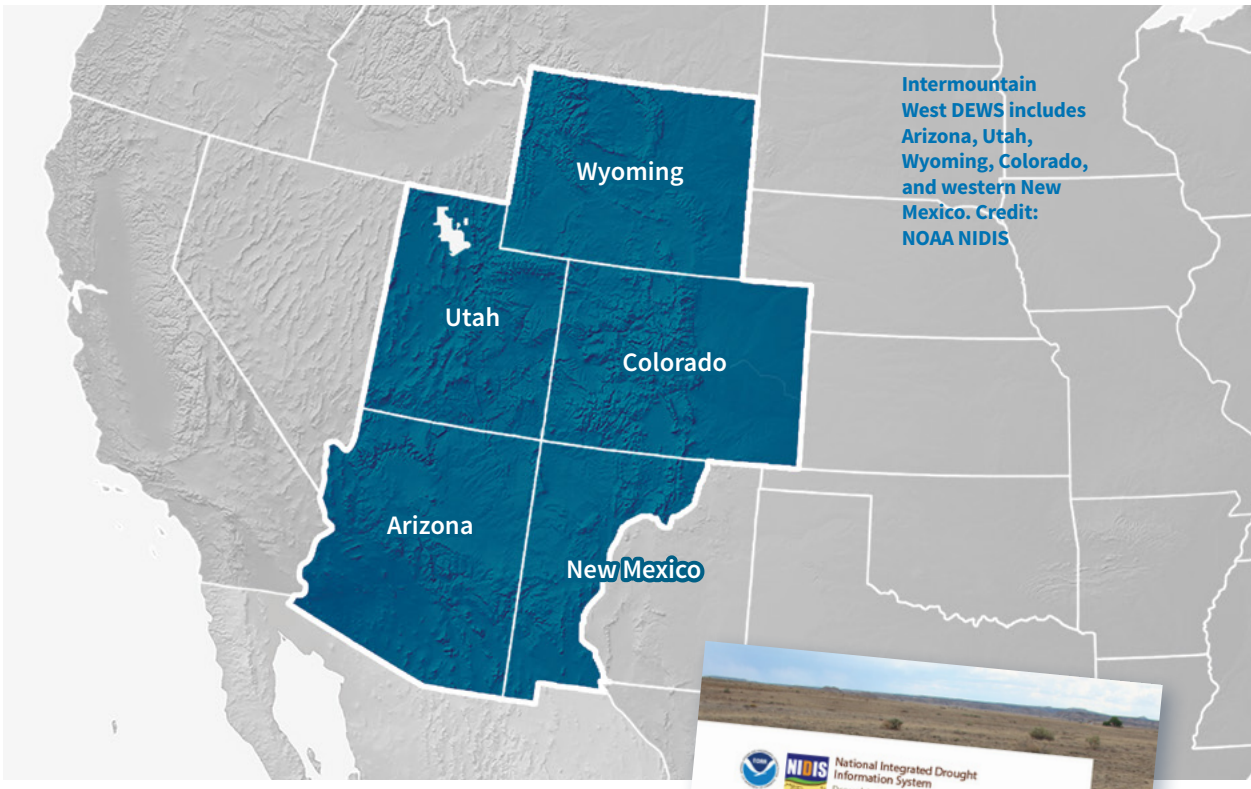
SOUTHWEST DROUGHT IMPACT ASSESSMENTS

In response to the 2017–2018 drought in the Southwest, NIDIS and partners are co-funding a project that will conduct economic impact assessments to understand and reduce the negative impacts and costs of future droughts. A Southwest regional impact assessment is being conducted along with state-level assessments for Arizona, Colorado, New Mexico, and Utah. The project is funded by NIDIS, the USDA Southwest Climate Hub, Colorado Water Conservation Board, Arizona Department of Water Resources, New Mexico Office of the State Engineer, and Utah Division of Water Resources.

DROUGHT IMPACTS ON OUTDOOR RECREATION IN THE INTERMOUNTAIN WEST

NIDIS partnered with the University of Colorado's Master of the Environment program to research the impact of drought on the outdoor recreation industry in the region. Over 112 water-based outdoor recreation businesses (ski resorts, snow-based, fishing, rafting, lake-based, and small retailers) were interviewed in 2019 and surveyed to determine drought impacts on their operations, adaptation strategies employed to mitigate negative drought impacts, and drought information needs to reduce the





Intermountain West DEWS includes Arizona, Utah, Wyoming, Colorado, and western New Mexico. Credit: NOAA NIDIS

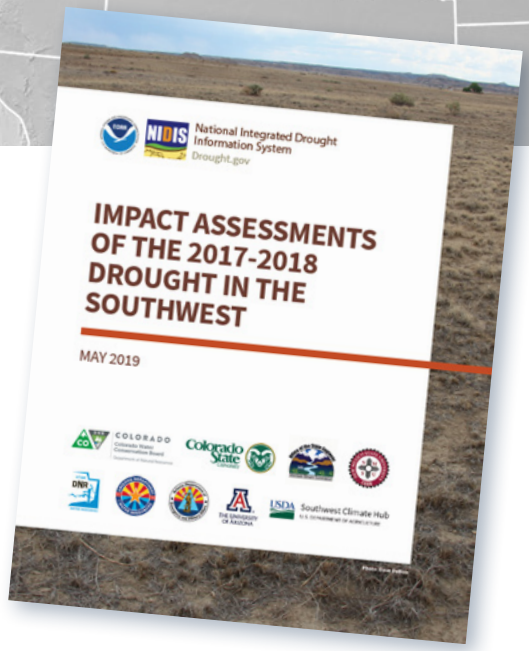
vulnerability of the industry. Research findings were presented at an industry seminar in November 2019.

IMW OPERATIONAL DROUGHT MONITORING AND COMMUNICATION

NIDIS provided funding throughout 2019 to the Office of Colorado's State Climatologist to provide weekly operational drought monitoring and communication for the Intermountain West region. This includes production of weekly climate, water, and drought assessments, webinars, and status reports that inform the U.S. Drought Monitor.

SUPPORTING CITIZEN SCIENCE CONDITION MONITORING

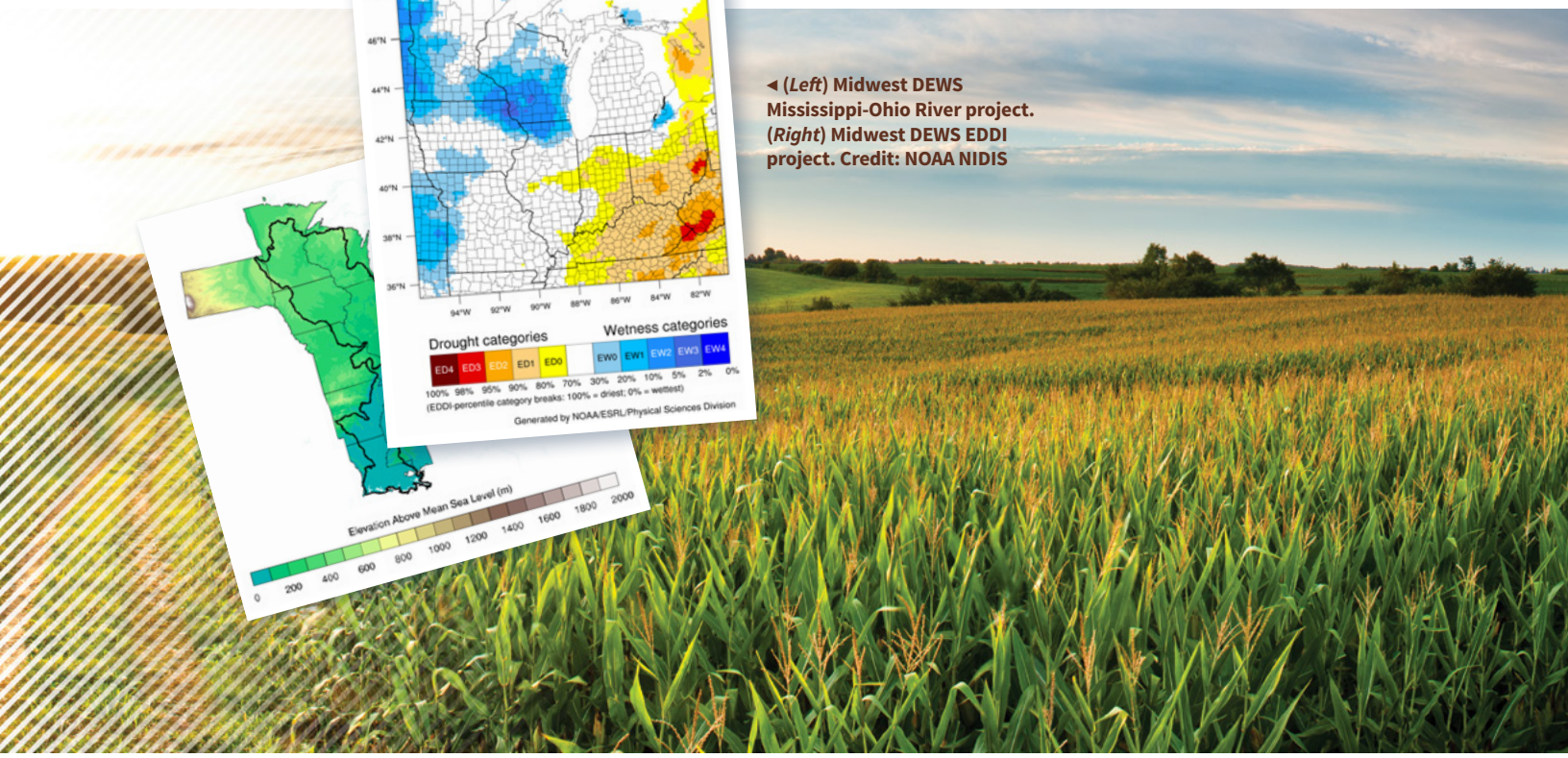
NIDIS supports the Office of Colorado's State Climatologist in their operation and maintenance of the CoCoRaHS network for citizen science condition monitoring. CoCoRaHS is a unique, non-profit, community-based network of volunteers of all ages and backgrounds working together to measure and map precipitation (rain, hail, and snow). In 2019, new citizen scientists were added to the network and CoCoRaHS online features and functionality were improved. CoCoRaHS provides valuable data that is integrated into the U.S. Drought Monitor.



► The report *Impact Assessments of the 2017–2018 Drought in the Southwest* was published in May 2019. Credit: NOAA NIDIS

DROUGHT TERMINATION AND AMELIORATION

NOAA's National Centers for Environmental Information (NCEI), with support from NIDIS, developed a Drought Termination and Amelioration Tool that shows the estimated amount of precipitation needed to bring a region out of drought. To solicit feedback on the tool, NIDIS sponsored a series of Drought Recovery workshops, including one in September 2019 in Boulder, CO. The workshop highlighted how this and other drought tools are used in the Intermountain West. □



◂ (*Left*) Midwest DEWS Mississippi-Ohio River project. (*Right*) Midwest DEWS EDDI project. Credit: NOAA NIDIS

MIDWEST DEWS

Over the last century, precipitation patterns in the Midwest have been trending towards wetter conditions and fewer droughts than the region experienced in the early 20th century. However, the Midwest continues to be challenged by droughts such as those in 1988 and 2012.

The 2012 drought led to nearly $35 billion in direct losses for the U.S., including closing the Mississippi River at least three times. These adverse impacts include limited barge transportation on major rivers, decreased agricultural production, challenges for municipal water supply and quality, and reduced productivity for hydropower. More recently, water managers have been challenged by rapid transitions from drought to flood and back to drought within short time spans.

▲ Sunrise over a cornfield with a silo. Credit: Larry Lindell

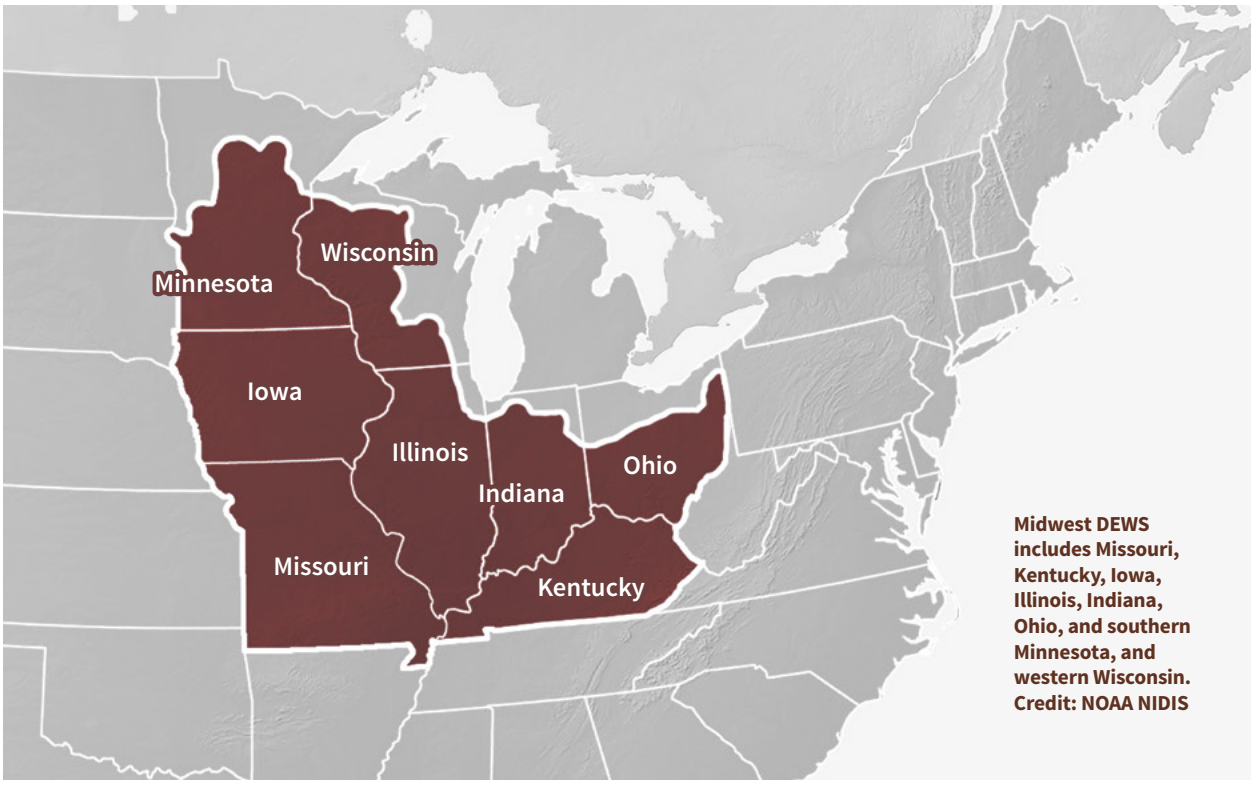
DROUGHT TRADE FOOTPRINT STUDY OF THE MISSISSIPPI RIVER

NIDIS, in partnership with the Mississippi River Cities and Towns Initiative (MRCTI), the USDA's Office of the Chief Economist, NOAA's Office of the Chief Economist, the U.S. Army Corps of Engineers, and other governmental and sectoral partners have joined forces to quantify drought impacts to the trade footprint along the Mississippi River Corridor in agricultural production, commercial river navigation and transportation, manufacturing, and recreation and tourism.

To better understand and address long-term drought risk, the project will identify 3–4 pilot locations to conduct community-based drought vulnerability assessments.

MIDWEST DEWS REGIONAL PARTNER MEETING

In November 2019, NIDIS hosted over 40 federal, tribal, state, local, academic and other partners from across economic sectors to discuss current and future drought activities, identify 3-year strategic priorities for the DEWS network, and learn about innovative drought data information and resources in the Midwest. Outcomes will be



Midwest DEWS includes Missouri, Kentucky, Iowa, Illinois, Indiana, Ohio, and southern Minnesota, and western Wisconsin. Credit: NOAA NIDIS

integrated into the Midwest Strategic Action Plan, to be released in 2020.

MIDWEST DROUGHT AND HUMAN HEALTH WORKSHOP

NIDIS, in partnership with the University of Nebraska Medical Center, Minnesota Department of Public Health, and the Minnesota Department of Natural Resources, hosted a Midwest Drought and Human Health Workshop in November 2019. The results of this workshop, along with five additional regional drought and human health workshops and a National Summit, will be integrated into a Drought and Human Health Strategy for NIDIS in 2021.

ONGOING PROJECTS TO IMPROVE EARLY WARNING

The study, "Characteristics, Predictability, and Risk of Mississippi and Ohio River Valley Drought," seeks to better understand the characteristics and physical mechanisms of drought in these river basins during its three phases: onset, persistence, and demise. The results of this study will be invaluable to help regional partners better understand what variables have driven historical droughts in the basins, which can help inform the most appropriate indicators to utilize for present-day drought monitoring. The results will also be useful in future climate and drought vulnerability assessments for partners across the region. The study is being conducted by NOAA's Earth System Research Laboratory's Physical Sciences Division (ESRL PSD).

The study, "Improving Drought Monitoring and Early Warning in the Midwest DEWS Using the Evaporative Demand Drought Index (EDDI)," will analyze historical drought events to evaluate the skill of EDDI in predicting these events, and at what time scale (e.g., 1-week, 1-month, 2-month). In addition, the project will develop a regional flash drought detection metric. The study is being conducted by NOAA's ESRL PSD.

With funding from NIDIS, the Kentucky State Climatologist is leading a project that includes installing additional soil moisture and temperature probes at 10 Kentucky Mesonet stations. Station data will be used to develop an interactive data visualization and analysis dashboard that integrates drought data from the Kentucky Mesonet and the U.S. Geological Survey. Dashboard-derived data will be regularly provided to state officials to inform management decisions. □

▲ The Missouri River flows between hills. Credit: Kavram

MISSOURI RIVER BASIN DEWS

Drought is a frequently occurring natural hazard in the Missouri River Basin (MRB). Significant drought events occurred in the 1930s and 1950s that substantially affected water supplies, crops and livestock, energy, transportation of goods, and the ecosystem.

In 2012, a large-scale drought event occurred. It was unique in that it followed a devastating flood across the MRB in 2011. The Upper Missouri River Basin was hit again in 2017 with a flash drought that led to agricultural losses alone totaling more than $2.6 billion dollars.

2017 DROUGHT IMPACT ASSESSMENT AND ATTRIBUTION STUDY

The 2017 Northern Plains flash drought sparked wildfires, destroyed livestock forage, and reduced agricultural production. Neither the drought's swift onset nor its severity were forecasted. In 2019, NIDIS and its state and Canadian partners published the report, *Flash Drought: Lessons Learned From the 2017 Drought Across the U.S. Northern Plains and Canadian Prairies*. The report examines the historic 2017 drought event and its impacts, identifies opportunities to improve timeliness of and accessibility to early warning information, and identifies applied research questions and opportunities to improve drought-related coordination and management within the MRB DEWS. In addition to the impact assessment, NIDIS published the report, The Causes, Predictability, and Historical Context of the 2017 U.S. Northern Great Plains Drought, which evaluates the causes, predictability, and historical context of the 2017 Northern Plains drought. The study was led by NOAA's Earth System Research Laboratory's Physical Sciences Division.

TRIBAL ENGAGEMENT IN THE MIDWEST AND MISSOURI RIVER BASIN

NIDIS partnered with the University of Colorado's Masters of Environment (MENV) Program in 2019 to improve collaboration with tribal nations in the Midwest and

The MRB DEWS includes Nebraska and parts of Montana, Wyoming, Colorado, Kansas, Missouri, Iowa, Minnesota, North Dakota, and South Dakota. Credit: NOAA NIDIS

Missouri River Basin DEWS. This initiative increased NIDIS's face to face engagement with tribal resource managers. NIDIS sought to better understand the current status of drought knowledge and planning in tribal nations, mapped and identified key drought vulnerabilities and capacity gaps of the tribes in both regions, and provided the tribes with tailored drought information. Lessons learned and key priorities moving forward are captured in a NIDIS Tribal Engagement Strategy.

MISSOURI RIVER BASIN DEWS REGIONAL PARTNER MEETING

In August 2019, NIDIS, together with the USDA Northern Plains Climate Hub, hosted a meeting in Billings, MT with federal, tribal, state, local, academic, private sector, and non-governmental partners to evaluate progress on the MRB DEWS Strategic Plan, identify 3-year strategic priorities for the DEWS network, and review the 2017 Flash Drought Impact Assessment and Attribution Study findings. Outcomes will be integrated into the MRB DEWS Strategic Action Plan, to be released in 2020.

STRENGTHENING EARLY WARNING IN THE UPPER MISSOURI RIVER BASIN

With NIDIS support, the Montana Climate Office, Montana Department of Natural Resources and Conservation, and the U.S. Forest Service are executing a project to better understand drought indicator applications for the region. The project will:

- Assess the key indicators of drought in the Upper Missouri River Basin (UMRB) and drought impacts in order to make reliable and timely forecasts of drought;
- Continue ongoing research and monitoring activities related to predicting drought;
- Build the technical capacity of the Montana Governor's Drought and Water Supply Advisory Committee through the development of automated drought mapping and summarization tools; and
- Provide timely drought information and products from watershed to regional scales. □

New England fall foliage. Credit: Kelsey Neukum

NORTHEAST DEWS

Known best for the autumn foliage, thick forests, rocky soils, and abundant freshwater resources, the northeastern United States is characterized by a diverse climate that is not often associated with drought. However, in 2016, New York and New England experienced historic drought conditions not seen since the 1960s.

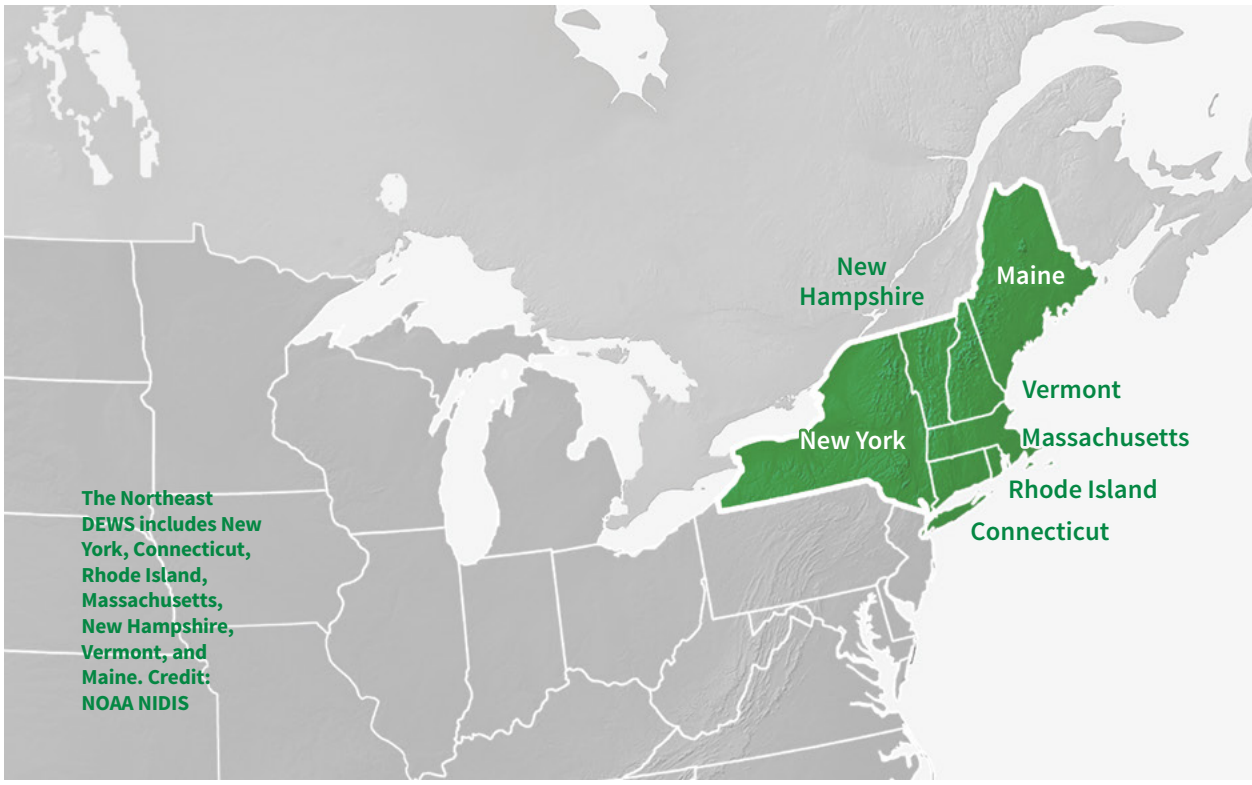
The Northeast also frequently experiences flash droughts that may last only 2–4 months, but can have profound negative impacts on the region.

NORTHEAST DEWS DROUGHT DASHBOARD

Following the launch of the Northeast DEWS in late 2017, Northeast Regional Climate Center (NRCC), in collaboration with NIDIS, developed a Northeast DEWS Drought Dashboard that provides a platform for decision makers to access federally produced drought data and indicators at the state level across the Northeast region. In 2019, the NRCC co-produced state-specific drought resources on the dashboard, including prototype county and drought district monitoring products summarizing precipitation deficits and drought indices at these spatial scales. The Northeast Drought Dashboard continues to be an expanding resource for state drought task force members, water utilities, agricultural producers, as well as members of the public to stay informed on drought conditions and outlooks across the region.

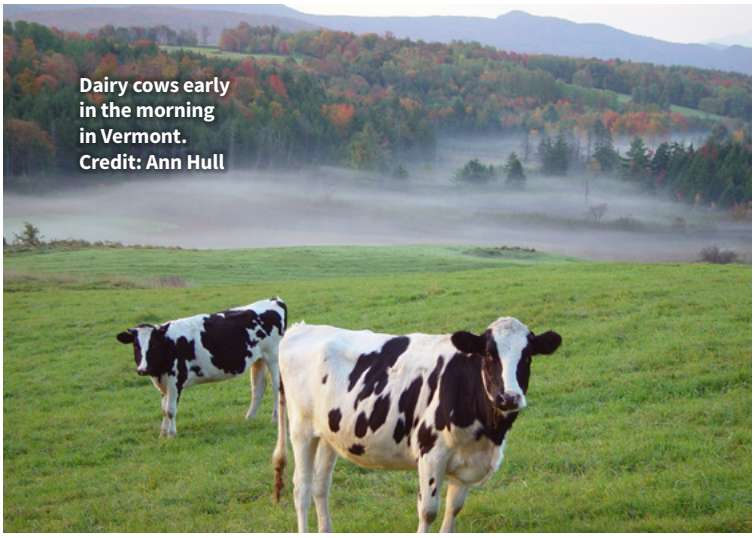
NORTHEAST DROUGHT MONITORING AND COMMUNICATION

NIDIS provided funding throughout 2019 to NRCC to coordinate input and deliver weekly assessments of drought in the Northeast, for the purposes of informing the U.S. Drought Monitor. This support also includes production of climate, water, and drought-related webinars, status reports, and briefing slide decks for regional stakeholders. □

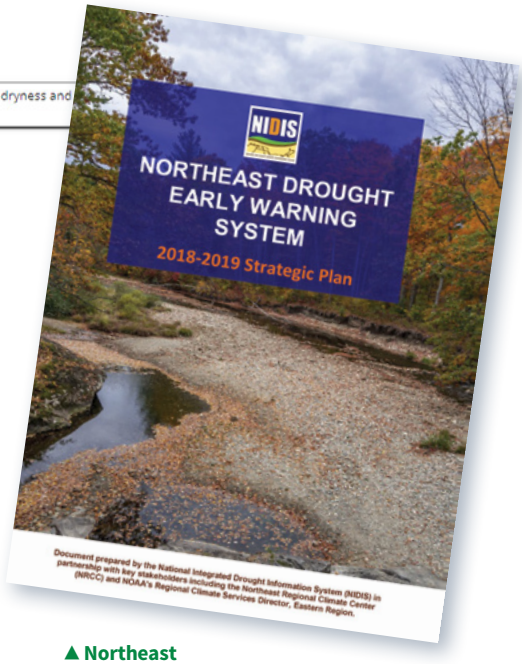


The Northeast DEWS includes New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, and Maine. Credit: NOAA NIDIS

◀ Northeast DEWS Dashboard. Credit: NOAA NIDIS



Dairy cows early in the morning in Vermont. Credit: Ann Hull



▲ Northeast DEWS 2018–2019 Strategic Plan. Credit: NOAA NIDIS

Autumn colors in Mount Rainier National Park. Credit: Mike Peters

PACIFIC NORTHWEST DEWS

The Pacific Northwest (PNW) is often associated with rainy forecasts, foggy days on the coast, and large scale irrigated agricultural projects in the arid interior. It is an ecologically diverse region heavily reliant on snowpack, precipitation, groundwater, and highly managed rivers for its water supply.

Despite its soggy reputation, the region experienced multiple droughts in the early 21st century. In 2015, virtually the entire region reached historic drought conditions. While the coastal regions experienced an unprecedented single-year drought, the eastern portions of Oregon and Idaho had been suffering under prolonged drought for four years.

PNW DEWS REGIONAL PARTNER MEETING

In October 2019, NIDIS hosted a meeting in Portland, OR with federal, tribal, state, local, academic, private sector, and non-governmental partners to discuss current and future drought activities, identify 3-year strategic priorities for the DEWS network, and learn about innovative drought data information and resources in the Pacific Northwest. Outcomes will be integrated into the PNW DEWS Strategic Action Plan, to be released in 2020.

WATER SUPPLY PLANNING

NIDIS supported Oregon, Washington, and Idaho with water supply planning by co-funding and participating in two November workshops. The Oregon-Washington workshop reviewed climate events and impacts of the 2019 water year, provided forecast information for the upcoming water year, and reviewed new resources on drought and climate variability. The Idaho Water Supply Outlook Meeting recapped the previous water year conditions, provided an outlook for the coming water year, and identified vulnerabilities and opportunities for increasing drought and climate resilience in the agricultural, power, and recreational sectors of Idaho's economy.

▲ Pacific Northwest Drought and Climate Outlook Webinar. Credit: NOAA NIDIS

The Pacific Northwest DEWS includes Idaho, Oregon, Washington, and part of Canada. Credit: NOAA NIDIS

AGRICULTURAL INSURANCE LOSS DUE TO DROUGHT

This research study examined agricultural insurance loss due to drought and other climatic events across the inland Pacific Northwest. The project, conducted by the University of Idaho, suggests that insurance loss may be a more sensitive barometer of climate impacts than production/yields, with variations based on geography, crop regime, climate, and commodity pricing. From this work, CIRC has developed a series of Agriculture Dashboards designed for farmers and researchers to examine the relationship between commodity losses at the state and county level to climate-related hazards, including drought, heat, frost, and freeze conditions.

INCREASING THE RESILIENCY OF SMALL WATER SUPPLIERS

NIDIS is funding a project, with support from the University of Washington Climate Impacts Group and the Office of the Washington State Climatologist, to increase the resiliency of small water suppliers to drought. The project will evaluate resources that can help small water suppliers increase the use of climate information, and facilitate long-term planning for drought and climate resilience, in order to reduce drought impacts on water supply and demand.

BUILDING DROUGHT RESILIENCE WITH DRY FARMING TECHNIQUES

NIDIS is funding an expansion of an Oregon State University Extension project that explores dry farming techniques as a drought and climate adaptation strategy. The project includes field research directly with farmers to further investigate the role of soil health management for improving the capacity of soil to hold moisture.

PNW DEWS DROUGHT AND CLIMATE WEBINARS

Pacific Northwest DEWS Drought & Climate Outlook Webinars were held every other month throughout 2019. These webinars provided the region's stakeholders with timely information on current and developing drought conditions, as well as climatic events like El Niño and La Niña. The webinars also discussed the impacts of these conditions on wildfires, water supplies, ecosystems, and high precipitation events as well as impacts to sectors like agriculture, tourism, and public health. Webinars were sponsored by NIDIS, the Climate Impacts Research Consortium (CIRC), USDA Northwest Climate Hub, and the NWS, Western Region. □

Windmill in a Texas field along Route 66 with a storm approaching. Credit: David P. Smith

SOUTHERN PLAINS DEWS

The Southern Plains DEWS contains diverse climates such as the semi-arid region of the Texas and Oklahoma panhandles and western Kansas, desert in eastern New Mexico and Big Bend Country of western Texas, and the hot, humid subtropical Gulf Coast.

With high rainfall variability from year-to-year, drought is a natural part of the climate pattern across the Southern Plains. Historically, droughts have been accompanied by heatwaves and dust storms. While droughts can occur during any time of the year, those that coincide with crop cycles can be especially costly. The Southern Plains can also experience extreme and sometimes hazardous weather including strong winds, hurricanes that cross the Gulf Coast, and severe thunderstorms that can sometimes produce tornadoes.

FORECAST-INFORMED RESERVOIR OPERATIONS WORKSHOP IN THE SOUTHERN PLAINS

Building upon the Forecast-Informed Reservoir Operations (FIRO) management strategy with the U.S. Army Corps of Engineers at Lake Mendocino in CA, NIDIS supported a workshop in September 2019 in Arlington, TX on new approaches in managing dams and reservoirs as a way to adapt to increases in climate variability and extremes. The workshop brought water sector agencies from the Southern Plains together with forecast providers, including NOAA, to identify obstacles that hinder the operational use of forecasts, and to spur actions to facilitate the adoption of FIRO demonstrated to be beneficial in other parts of the nation. The workshop was organized by the Texas Water Development Board and the University of Texas at Arlington at the request of the states of Texas and Oklahoma.

IMPROVING THE USE OF DROUGHT INFORMATION IN MANAGING WILDLAND FIRES

The NIDIS Drought and Wildland Fire Nexus (NDAWN) defines the needs and challenges of fire managers to

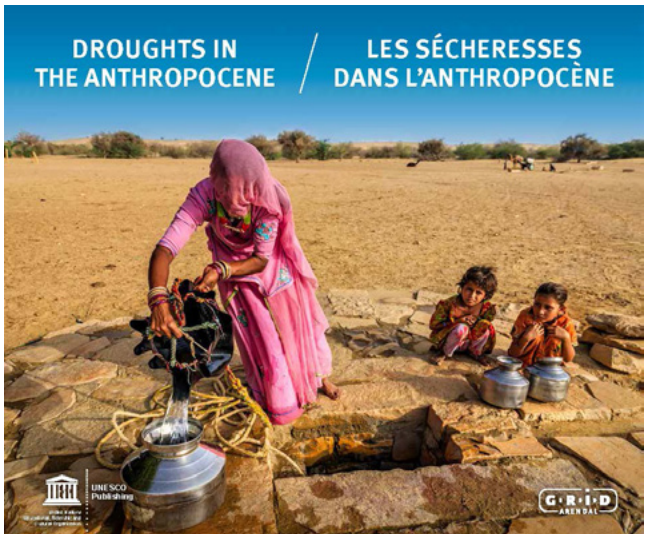
▲ The Southern Plains DEWS includes Texas, Oklahoma, and parts of New Mexico and Kansas.Credit: NOAA NIDIS

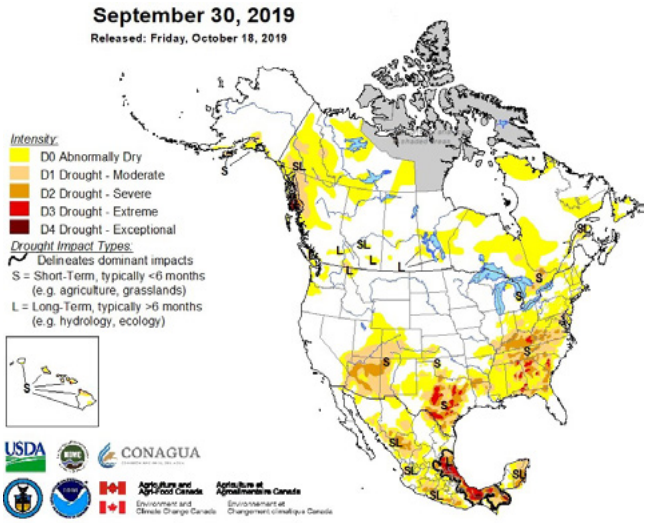
effectively utilize drought information and aims to meet those needs and to establish a robust drought and wildland fire decision-support information network. In fall 2019, NDAWN partners convened subregional workshops in Texas and Oklahoma to bring together drought experts, fire planners, emergency managers, and fire behavior experts to identify key topics related to drought and wildfire impacts in grass-driven systems. The NDAWN initiative is supported by NIDIS, DRI, and WRCC.

DROUGHT COMMUNICATION GUIDE

NIDIS and the Southern Climate Impacts Planning Program (SCIPP), a NOAA RISA, developed a Drought Communication Guide to serve as a resource for Southern Plains community leaders in their encouragement of the public to take action during drought. The document contains sample social media posts, tip sheets, messaging, and resources about topics such as conserving water, preventing wildfires, and protecting wildlife. Each topic contains background information about the impacts of drought and recommendations for how citizens can manage their homes and activities to reduce those impacts. □

▲ Longhorn cattle in field in Dallas Texas. Credit: Douglas Knight





INTERNATIONAL

NIDIS engages in select global drought activities where our expertise and knowledge contribute to greater drought resiliency worldwide, thereby reducing national security risks, and where NIDIS can learn and apply new knowledge to drought early warning in the U.S.

▲ (*Left*) *Droughts in the Anthropocene* front cover. Credit: iStock/Bartosz Hadyniak. (*Right*) *North American Drought Monitor*. Sept. 20, 2019. Credit: USDA, NDMC, DOC, NOAA, CONAGUA, Agriculture and Agri-Food Canada

DEVELOPING GUIDELINES ON NORTH AMERICAN DROUGHT INDICES

NIDIS and partners are working with the Commission for Environmental Cooperation, an intergovernmental organization that supports cooperation among the United States, Mexico and Canada, to develop guidelines on the use of locally-relevant drought indices for North American climatic regions. The group will also make recommendations for communities to improve access to, and use of, tools for multi-hazard planning and drought, including the North American Drought Monitor.

DROUGHTS IN THE ANTHROPOCENE

In the Anthropocene, the ongoing period in which humans are the dominant influence on climate and the environment, droughts are closely entwined with human actions, cultures, and responses. The United Nations Educational, Scientific and Cultural Organization (UNESCO), in partnership with NIDIS and others, produced 15 case studies from around the world showcasing the social, environmental and cultural impacts of droughts and water scarcity. These case studies, presented through a report and videos, highlight solutions to better address the impact of droughts worldwide.

DROUGHT RISK MANAGEMENT WITH THE WORLD METEOROLOGICAL ORGANIZATION

NIDIS represents Region IV (North American, Central America and the Caribbean) on the World Meteorological Organization (WMO) Commission for Agricultural Meteorology's Expert Team on Drought. This Expert Team is examining the status of regional and countrywide drought monitoring systems, assessing drought impacts such as agricultural losses, and creating guidance on incorporating national drought alerts and warnings into regional multi-hazard early warning systems and global alert systems. □

NIDIS PARTNERS

NIDIS partners with dozens of agencies across the federal government:

U.S. Department of Agriculture (USDA)
- Agricultural Research Service
  - Climate Hubs (NIDIS Executive Council Member)
- Cooperative State Research, Education, & Extension
- Farm Service Agency
- Forest Service
- National Agricultural Statistics Service
- Natural Resources Conservation Service Risk Management Agency

U.S. Department of Commerce (DoC)
- International Trade Administration
- National Oceanic & Atmospheric Administration

U.S. Department of Energy (DoE)
- Office of Electricity Delivery & Energy Reliability
- Office of Energy Efficiency & Renewable Energy
- Office of Science

U.S. Department of Homeland Security (DHS)
- Federal Emergency Management Agency (FEMA)

U.S. Department of the Interior (DoI)
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Reclamation
- National Park Service
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

U.S. Department of Transportation (DoT)
- Federal Aviation Administration
- Federal Highway Administration
- Surface Transportation Board

Army Corps of Engineers

Environmental Protection Agency (EPA)

Farm Credit Administration (FCA)

National Aeronautics & Space Administration (NASA)

National Science Foundation (NSF)

Small Business Administration (SBA)

U.S. Department of Health And Human Services (HHS)

Centers For Disease Control & Prevention (CDC)

Additionally, NIDIS partners with hundreds of national, tribal, state, and local governments and agencies, plus academia, nonprofit organizations, and the private sector.

NIDIS BY THE NUMBERS

2019

47 **Research projects/ resource developments ongoing/completed**

90 **Webinars**

21 **Workshops**

Twitter
5,186 followers
13% increase in followers

Facebook
1,240 followers
40% increase in followers

YouTube
3,310 views
485.8 hours watch time

U.S. Drought Portal
www.drought.gov
2,037,451 page views
621,301 users
Average session duration: 9:01 min.
10% increase page views (+193,584)
6% increase in users (+32,401)
42% increase in average duration (+2:65 min.)

NIDIS biweekly newsletter
Dry Times
4,000 subscribers
280,000 newsletters sent
82,641 opens
16,504 clicks
33% open rate, 12% higher than industry average (Constant Contact)
20% click rate, 12% higher than industry average (Constant Contact)

www.drought.gov

Have questions about the report? Please contact:
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