Making an Impact on Extreme Events and Cascading Hazards

Tracking Tropical Cyclones and Monitoring Droughts

The United States has experienced extreme weather and climate events in the past, but they have been getting worse in recent years. With climate change, these events are expected to increase even more in frequency, intensity and duration in the coming decades. Many strike like fast-moving wrecking balls, imposing considerable damage and disruption to life, property and our natural resources.

When environmental extremes strike—such as persistent heatwaves, unusually severe, or long-lasting drought, or atmospheric rivers that trigger flooding and mudslides—NESDIS and our skilled employees are ready. NESDIS provides state-of-the-art observations, long-term data records, and information used by communities around the world in the face of extreme weather events. The following are two key areas where NESDIS scientists are making an impact.

Predicting the Birth of a Storm with the NESDIS Tropical Cyclone Formation Product

Tropical cyclones form in every tropical and subtropical oceanic region. A natural occurrence, cyclones bring many hazards to both coastal and inland areas, including heavy rain, strong winds, and floods. All can disrupt human and natural systems, including transportation and energy transmission infrastructure, coastal ecosystems, ocean commerce, and marine operations, as well as health and well-being. Nearly two billion people worldwide have been exposed to hazardous cyclone weather in coastal regions. With coastal populations growing and sea level rising, more people are at risk.

Between 80 and 100 cyclones form in a given year over vast ocean regions with sea surface temperatures greater than 26°C (~30 million square miles). Cyclones typically intensify to hurricane strength within 72 hours of formation.

Public attention is often captured quickly, as weather forecasts of future movement and intensity changes begin once a tropical cyclone forms. NOAA works with the Department of Defense (DoD) and international organizations to forecast global tropical cyclone activity—crucial to coastal warnings, preparedness, and mitigation.

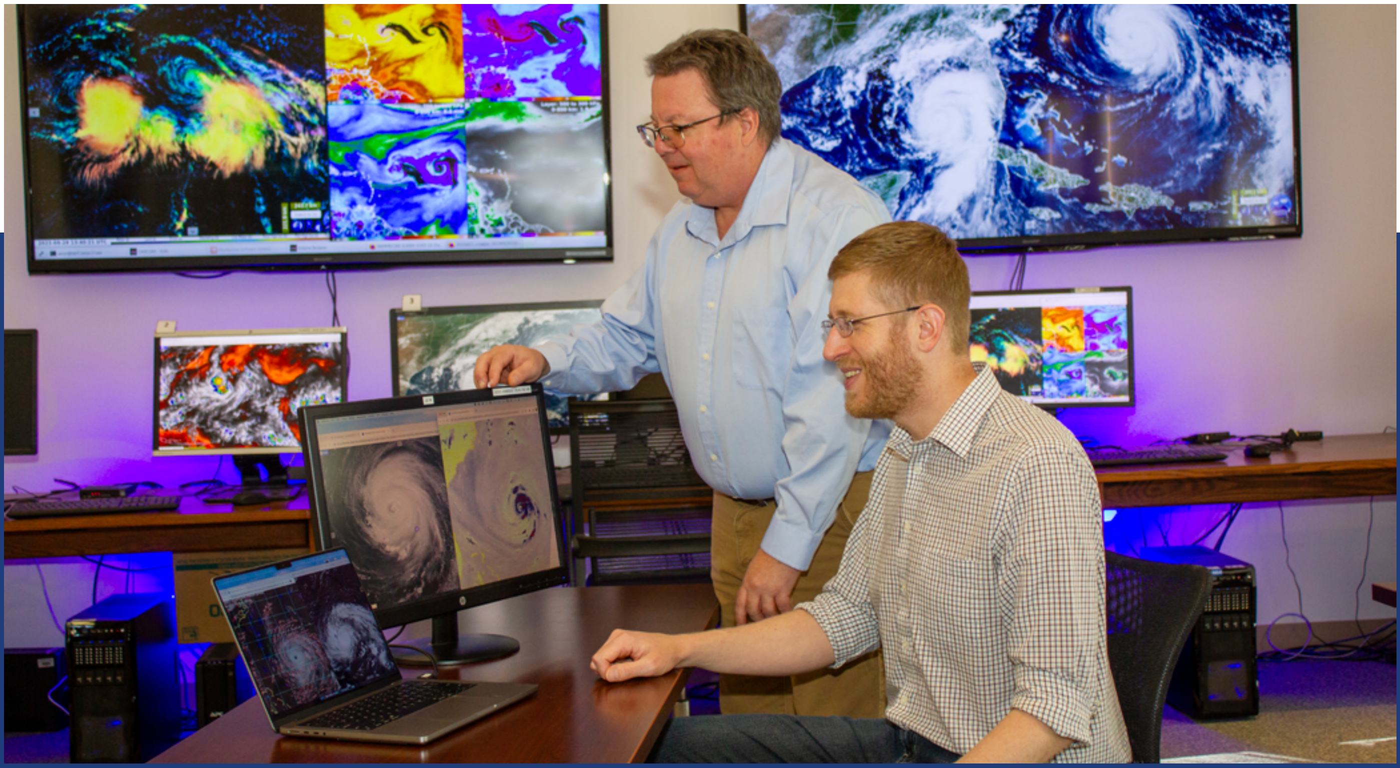
Updates, Improvements, and Cloud Implementation

NESDIS scientists Dr. Christopher Slocum and Dr. John Knaff are working to improve the global prediction of the genesis of tropical cyclones. The pair developed an algorithm leveraging three elements:

- Environmental conditions, such as winds with altitude and the amount of energy available to develop and strengthen cyclones;
- Satellite observations of thunderstorm activity; and
- Locations of current tropical cyclones (existence of which prevents tropical cyclones from forming nearby).

A specialist in tropical cyclone dynamics, applications from geostationary platforms, and machine learning, Slocum updated a legacy tropical cyclone formation product using several machine learning algorithms to improve both calibration and forecast performance. Knaff, whose research centers on the observational aspects of hurricane structure and intensity variations and prediction, managed the project. They were supported by NESDIS IT specialists who readied the algorithm for operations on the NOAA Common Cloud Framework, bringing it over the finish line.

Outputs from the algorithm are displayed in real-time, archived for future use, and provided to NOAA, the



Dr. John Knaff and Dr. Chris Slocum used machine learning to develop an algorithm to predict tropical cyclone formation probabilities.

DoD, and other users, offering insight into current conditions and seasonal activity.

The algorithm combines satellite observations of real-time thunderstorm activity with global models of environmental conditions to predict 0-to-48 hour tropical cyclone formation probabilities. Slocum and Knaff's work suggests that machine learning can significantly improve storm forecasting. Higher quality data can provide more accuracy, greater temporal resolution, certainty, and precision.

Slocum and Knaff anticipate using a combination of machine learning and synthetic satellite information to extend formation probability to longer lead times (5–7 days).

Helping Tackle the Many Dimensions of Drought

One of the most pervasive and devastating climate-related disasters is drought. Climate change is driving the severity, duration, and frequency of drought. According to NOAA's Global Drought report, at the end of July 2023, drought was affecting every continent of the globe, including 63 percent of Europe, 27 percent of North America, and 19 percent of Africa.

Drought is a deficiency of precipitation over an extended period of time. It has plagued society for thousands of years, even potentially contributing to the collapse of some early civilizations. Drought affects every sector of society, including recreation, transportation, city water supply, power generation, agriculture, and national security.

In the U.S., drought has most notably affected the arid lands of the western U.S. that depend on melted mountain snowpack to meet summer water demand. That's changing as warmer temperatures cause more of the winter precipitation to fall as rain instead of snow, reducing winter snowpack, and consequently, the summer water supply. The combination of declining snowpack and prolonged dry and hot periods is creating "mega-droughts" —droughts that last not years, but decades.

NOAA scientists play a key role in monitoring the nation's drought conditions. Scientists such as Richard Heim and other drought experts at NESDIS are working to solve the toughest drought-related challenges. Heim's projects include refining drought monitoring tools, and writing the monthly State of the

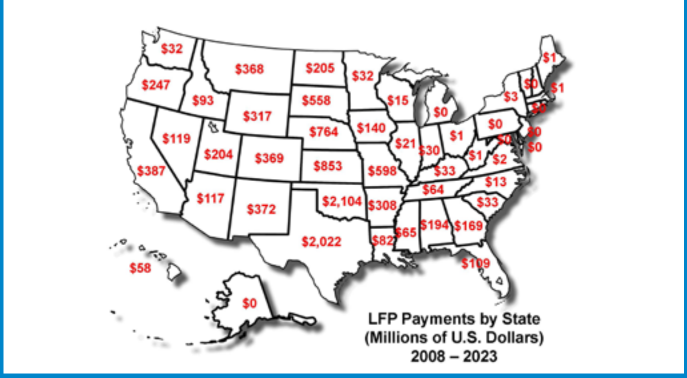
Effects of Drought on our Environment

The summer of 2023 was especially dry and hot across the United States, from the Upper Midwest down through the southern Plains and the Lower Mississippi Valley. Louisiana saw its driest and hottest August. Mississippi had its hottest August. Minnesota and Wisconsin had their fourth-driest stretch from May through August. Soils were parched, crops withered, and lakes, rivers, and ponds dried up.

Drought is reducing yields and increasing costs on U.S. agriculture. The USDA's Livestock Forage Disaster Program (LFP) provides payments to eligible livestock owners and contract growers who have suffered a loss of grazed forage due to a qualifying drought during the normal grazing period for their county. Payouts under LFP from 2008–2023 have totaled $11.11B.

Dry stock pond in Texas, September 2023. Source: National Drought Mitigation Center Condition Monitoring Observer Reports.

Livestock Forage Disaster Program (LFP) payouts in millions of dollars, each year from 2008-2023 (2023 totals are incomplete). Source: U.S. Department of Agriculture.



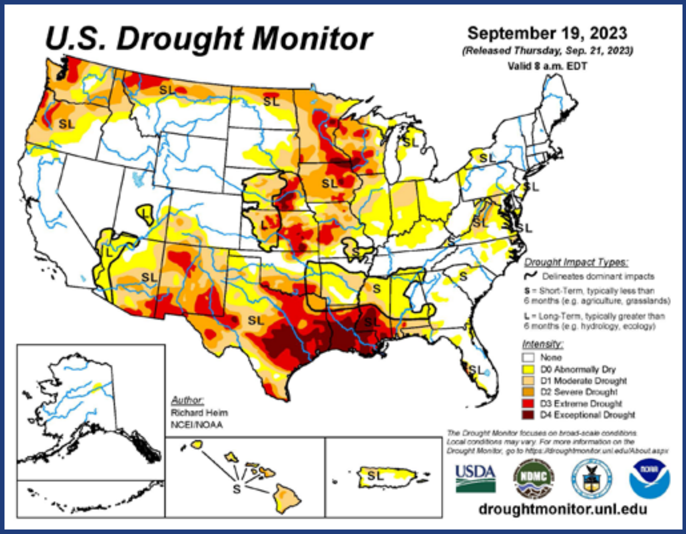
Livestock Forage Disaster Program (LFP) payments by state, in millions of dollars, totals for 2008-2023. Source: U.S. Department of Agriculture.

[Climate Drought report] for the National Centers for Environmental Information (NCEI). Heim is also a lead author of a [journal article] summarizing domestic and international user engagement workshops that helped define drought monitoring parameters and needs in the diverse climates of North America.

Drought poses other challenges, as a slow-moving and largely unseen phenomenon. To illustrate this, Heim compared droughts to hurricanes.

> ***"You can see a hurricane coming—its wind speed, size, speed, and direction of movement can all be calculated and prepared for in real-time", Heim said. "Drought, however, is the absence of something, specifically precipitation. It develops slowly, from the lack of rain, or as the reduction of precipitation builds up deficits from what normally occurs over time and, at some point, impacts begin to be felt."***
>
> *—Richard Heim*

Since January 2000, NOAA, the United States Department of Agriculture (USDA), and the National Drought Mitigation Center have collaborated with hundreds of local experts across the 50 states and U.S. territories to produce a weekly drought map and narrative known as the U.S. Drought Monitor (USDM). Heim and his NESDIS colleague, Rocky Bilotta, contribute as authors to the USDM. NCEI led the development of a data platform that supports the USDM in the U.S.- Affiliated Pacific Islands, and hosts the National Integrated Drought Information System (NIDIS) drought.gov web platform, a multi-agency effort. Led by NOAA, NIDIS coordinates drought monitoring, forecasting, planning, and information at national, tribal, state, and local levels. NIDIS enables communities to better prepare for, respond to, and recover from drought.



U.S. Drought Monitor map for September 19, 2023. The map shows the occurrences of the most extreme drought: the southern Plains to Lower Mississippi Valley, central Plains, and Upper Mississippi Valley. Source: National Drought Mitigation Center.

In 2002, NCEI led the expansion of drought monitoring across North America with the development of the monthly North American Drought Monitor (NADM), prepared from the corresponding USDM, Mexican Drought Monitor, and Canadian Drought Monitor and produced collaboratively by agencies from all three countries. NOAA/NESDIS also developed and hosts the Global Drought Information System (GDIS) and its Global Drought Monitor, which includes global drought maps updated each month, and a Global Drought Narrative, which discusses drought conditions on each continent.

Our changing climate means more extreme weather events such as cyclones and increased likelihood of hazards such as droughts. NOAA is responding to these challenges by providing both the technology and brainpower to help those both in the U.S. and around the world predict, endure, and recover from extreme events and hazards.