State of the Science FACT SHEET

US Drought

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

Droughts are among the most damaging of all natural hazards, with annual economic losses for the US in the billions of dollars extending through water resources, crop production, ecosystems, energy, transportation networks, wild-fire risks, and public health. Drought differs from most other hazards in the nature of its onset and duration, and in the accumulation of its impacts over months and years, and can span spatial scales from small watersheds to thousands of square miles.

How is Drought Defined?

Drought is a naturally recurrent hydroclimate process broadly defined as an "anomalous deficit in moisture relative to a normal baseline" in one or more components of the hydro-climatological cycle, and can significantly affect the condition and functioning of water-sensitive resource sectors, communities, species, and ecosystems. These components include water storage and cycling in the atmosphere, in soils, rivers, lakes/wetlands, reservoirs, snow-pack and groundwater. Thus, drought is classified based on at what stage in the hydrological cycle and in which locations these moisture anomalies occur. Droughts often begin as precipitation deficits (meteorological drought) propagating over time (typically days to years) through the hydrologic cycle to affect soil moisture (agricultural drought) and resulting in reductions in snowpack, runoff, streamflow, storage aquifers and surface reservoirs (hydrological drought). Precipitation deficits, along with other factors, can drive droughts to evolve much more rapidly over weeks to months. From May to July 2012, one such event, now referred to as a "flash drought," resulted in an increase of the areal extent of drought from 30 to 60% of the United States in less than three months.

How Have Droughts and Impacts Varied Over the US?

The fraction of the US in moderate drought or worse exhibits high variability over time (Figure 1), averaging about 20% but ranging from less than 5% to as much as 80%. Specific events have remained strongly embedded in the American experience. For example:

- The "Dust Bowl" of 1930-1940 was the most extensive drought over the continental US in the modern observational record, with 68% of the nation experiencing severe to extreme drought.
- The 1950s drought affected up to 60% of the country interspersed with significant precipitation events.
- The 2012 drought with around 65% of the country in moderate to extreme drought, and the 2007 Southeast Drought further illustrate that droughts are issues of concern across the Nation.

NOAA's National Centers for Environmental Information estimates 31 droughts between 1980 to 2024 (August) cost the nation at least $361 billion, and resulted in over 4,500 deaths when compounding drought and heat events are included. These numbers, while significant, do not include estimates of secondary and higher-order impacts as they cascade through economies, ecosystems, and livelihoods, nor of cumulative impacts of sequences of smaller events. While there are no long-term trends indicating an increase in drought conditions, the percent of the US experiencing moderate to severe drought increased and remained at elevated levels during the first two

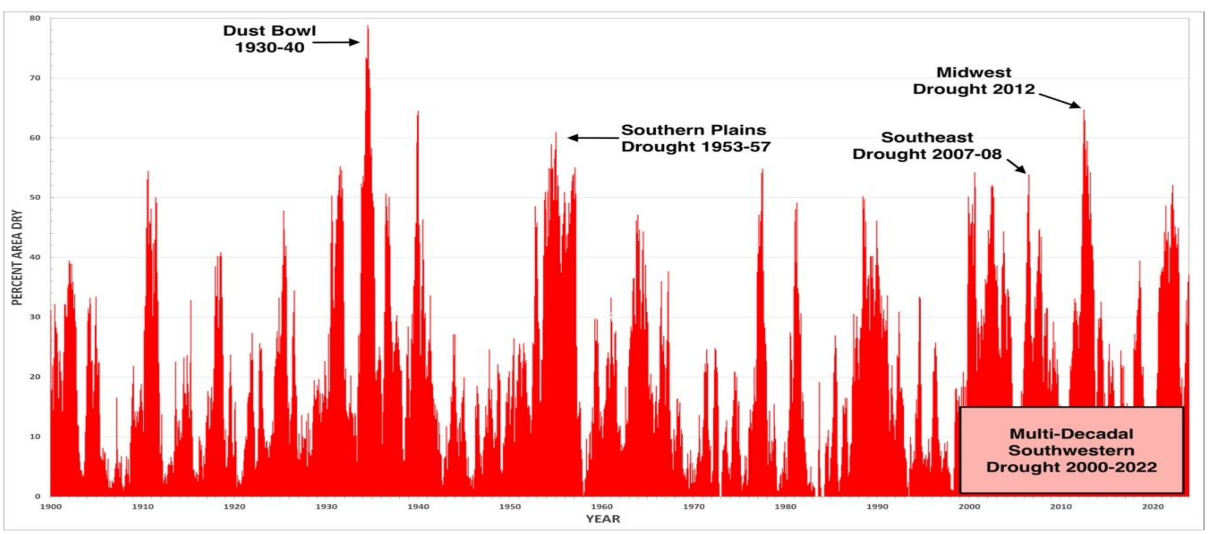

Figure 1. Percent of US in Moderate to Extreme Drought based on the Palmer Drought Index. Selected years show that droughts can last for multiple years and occur across US regions.

decades of the 21st century. Paleo-records and regional soil moisture constructions for the Southwest US rank 2000–2021 CE as one of the two driest 22-year soil moisture periods in the last 1200 years, comparable to the 1571-1592 CE period.

What are the Primary Causes of Drought?

The major drivers of drought across North America result from atmospheric circulation anomalies forced by large scale sea surface temperature variations in the tropical Pacific and Atlantic Oceans. Resulting atmospheric blocking patterns shift storms away from the affected regions. Persistent blocking patterns also can lead to higher daytime temperatures and increased evaporation, hence drier soils. Multi-year droughts are attributed to a combination of ocean forcing (especially persistent La Niña conditions for the US Southwest) and land-atmosphere interactions. In the US Southwest, an important driver of precipitation reductions in the first two decades of the 21st Century is a change and persistent turn towards the cool (or negative) phase of the Pacific Decadal Oscillation beginning at the turn of the century. Although the natural precipitation deficits alone would have established twenty-first-century drought conditions in the Southwest, the region has also experienced significant increases in vapor pressure deficit owing to warmer temperatures, modified by factors such as humidity and wind. The characteristics of a particular drought event in a region or locale are strongly influenced by internal atmospheric variability and evaporative demand. For example, sea surface temperature forcing was not a significant factor for the 1988 Northern Plains drought, while a failure of moisture transport from the Gulf of Mexico led to the 2012 Great Plains drought.

Drought in a Changing Climate

Warmer temperatures due to the changing climate increase evaporative demand in the atmosphere and lead to increased moisture loss from the surface. Warmer temperatures also increase the fraction of precipitation falling as rain rather than snow, thus advancing the timing of the snowmelt season in the spring. This is especially critical in the West, where spring melting of the winter mountain snowpack provides a critical water source during the summer dry season. Evidence of a climate change signal was identified in the major drought that affected California from 2011–2016. This period was characterized by severe deficits across the hydrologic cycle. Studies conclude that the precipitation deficits were dominated by natural variability. The importance of the compounding effect of direct temperature increases on drought impacts is one of the most critical remaining uncertainties. In addition, the influences of climate change on modes of variability are the focus of present research attention, including El Niño–Southern Oscillation (ENSO), large-scale atmospheric circulation, surface moisture versus soil column depth moisture, and vegetation feedback. Increasing confidence in climate change projections of drought and the associated impacts will depend on resolving uncertainties in processes such as land-atmosphere interactions, precipitation processes and changes in atmospheric circulation.

NOAA Priorities

NOAA focuses on observations, research, predictions, and the development and implementation of early warning information systems including the National Integrated Drought Information System (NIDIS), to inform risk management and to increase the Nation's resilience to drought. Examples of efforts include, but are not limited to:

- Identifying sources of predictability and improving precipitation predictions and outlooks, including at sub seasonal to seasonal timescales, through NOAA's Precipitation Prediction Grand Challenge.
- Advancing the cross-timescale prediction of sea surface temperature variations, atmospheric circulation anomalies and blocking patterns resulting in drought.
- Applying advances in ocean/land/atmospheric observations, data assimilation, and hydrologic modeling to improve forecasts and outlooks.
- Improving drought monitoring, especially estimates of snow water storage, satellite-based vegetation conditions, and the development of a National Coordinated Soil Moisture Monitoring Network.
- Incorporating monitoring and real-time analyses of precipitation, temperature, soil moisture, snowpack, vegetation/crop stress, groundwater, river and lake levels into a national drought early warning information system.
- Understanding and reducing impacts of droughts on protected species (e.g., salmon, steelhead, sturgeon).
- Understanding the effects of long-term temperature changes on drought severity and impacts.
- Assessing the cascading and compounding economic and health impacts of drought and related hazards.
- Understanding transitions from floods to droughts and back to guide forecast-informed water management, in collaboration with US Army Corps of Engineers and the Department of Interior, among others.
- Improving drought information service delivery mechanisms, communication, and decision support.

NOAA Resources

- Office of Oceanic and Atmospheric Research (OAR) including through the NIDIS (drought.gov), Climate Program Office research programs, and water cycle and drought research at the Physical Sciences and Geophysical Fluid Dynamics Laboratories.
- National Weather Service (NWS), including the Climate Prediction Center, Environmental Modeling Center, Office of Water Prediction, National Water Center, and River Forecast Centers.
- National Environmental Satellite, Data, and Information Service (NESDIS), including the Office of Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO) Observations, the National Centers for Environmental Information and Center for Satellite Applications and Research and the Office of Satellite and Product Operations.