Earth Gauge

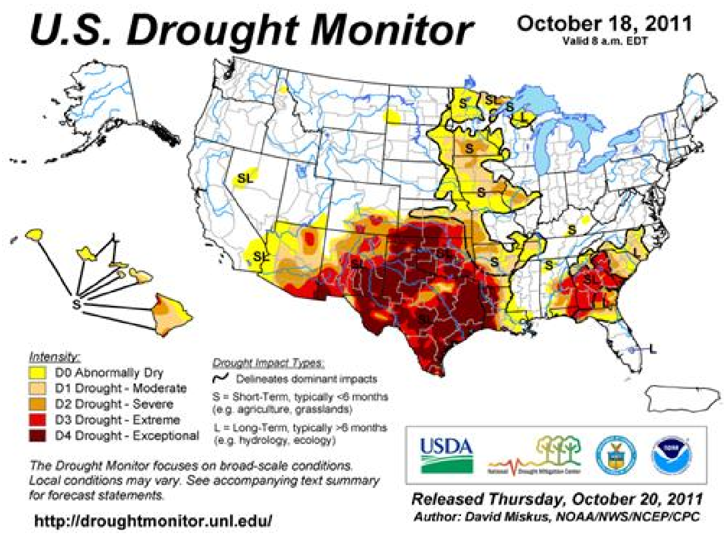
A National Environmental Education Foundation Program

Droughts in North America

Drought is one of the costliest weather-related natural disasters, causing between six and eight billion dollars in damages worldwide each year and accounting for around one-third of natural disaster costs in the United States. At the end of September 2011, about ten percent of the United States was in the worst category of drought (exceptional) and 4.2 percent of the United States (from parts of New Mexico eastward into Texas and Oklahoma) was under the worst drought conditions since 1900. What does it mean to be in drought? How do current droughts compare to droughts that have occurred over the past millennia?

What is Drought?

A drought is an abnormally dry period that persists for long enough to affect crops, wildlife and people accustomed to having more available water. There are several different classifications of drought: ***meteorological drought*** is defined by below normal rainfall in a given area; ***agricultural drought*** occurs when soil moisture is no longer sufficient to meet the needs of a crop that ordinarily grows in a certain area; ***hydrological drought*** occurs when surface and subsurface water supplies are below normal; and ***socioeconomic drought*** occurs when water shortages are severe enough to directly affect people. Only one of these drought types is defined solely by precipitation. Lots of evaporation induced by abnormally high temperatures can lead to drought even if rainfall levels are normal.



Above: The U.S. Drought Monitor report from October 18, 2011. Note the scale from D0 (yellow, abnormally dry) to D4 (dark red, exceptional drought). About four percent of the United States is under record drought conditions.

Abnormally Dry: Compared to What?

By the definition above, a drought is an abnormal event. But what is "normal?" While the current drought in the South Central United States is severe by centennial standards, have similar events occurred over the past several thousand years? How about the past 500,000 or five million years? Earth's climate undergoes significant changes on different time scales. What is "normal" to those of us living in the 21st century may be abnormally wet or abnormally dry when conditions are averaged over longer time-scales.

For example, drought conditions in the Southwest today are beginning to resemble drought conditions experienced there in the 1950s and 1930s. Looking over the past millennia, it is likely that droughts of similar or greater intensity persisted for centuries, such as during the 14th and 15th centuries. Over the past 500,000 years, droughts lasting as long as many centuries or even thousands of years have occurred. During some of these droughts, average annual temperatures in the Southwest were 11 degrees Fahrenheit warmer and both winter and summertime precipitation levels were much lower than those experienced today. On the other hand, the early part of the 20th century was one of the wettest periods in the Southwest since at least 1400. These climatic conditions formed the basis for Colorado River water allocations, which are still in effect today.

While the absolute amount of rainfall is important, the frequency of fluctuations between wet and dry periods is also an important factor for local ecosystems and people. In Minnesota, the 20th century was a period of relative rainfall stability. Much greater fluctuations occurred during the 3,000 years prior to 1900, particularly during the 12th and 13th centuries, which preceded the transition of the region from open woodland to "big woods" forest. Sudden shifts or rapid fluctuations in climate, regardless of the direction, can have major impacts on plant communities accustomed to stable temperature and moisture conditions; ecosystems can respond unexpectedly.

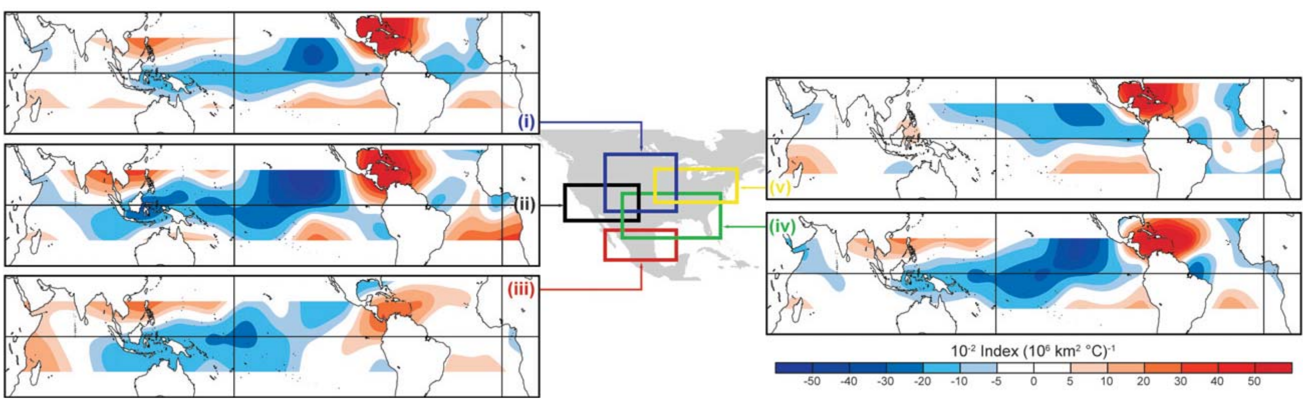
Drought Drivers

Sea surface temperature departures from normal (particularly in the tropics) and land-surface conditions are the two variables that can explain the most about how North American drought conditions develop.

Sea Surface Temperatures: Some specific locations in the world's oceans have the potential to exert a strong influence on North American rainfall. The eastern tropical Pacific is one of these locations, with cool (La Niña) phases of the *El Niño-Southern Oscillation (ENSO)* causing the Pacific Storm track to shift northward, leaving the Southwest and central United States drier than normal during winter. The dry conditions in the Southwest during the Middle Ages have been linked to a persistently cool tropical Pacific.

A warm tropical and sub-tropical North Atlantic is associated with dry conditions throughout the United States, particularly in the West and Great Plains regions. The North Atlantic has been warmer than average for the past 40 years and has warmed more than any other ocean basin during this period. A warm tropical North Atlantic means a weaker *North Atlantic Subtropical High (NASH)* over the Gulf of Mexico and Southeast United States. This allows drier northerly and southwesterly winds to blow into the Great Plains region, particularly during the warm months. A weaker NASH means less moisture flux from the Gulf of Mexico and less warm season rainfall. Where the Gulf of Mexico moisture ceases to have influence is called the *dry line* – today, it is as far west as eastern Wyoming. During the Medieval drought period, the *dry line* was likely farther east than it is today. While the tropical Pacific and tropical North Atlantic are both clearly important to drought development in North America, other locations around the world's oceans are potentially influential as well. Temperature variability of the tropical Pacific is probably the most understood and recognized driver of drought, but other locations such as the Indian Ocean, where temperature variability is not as pronounced, may be just as important on longer time scales.

Outside of the tropics, knowing the current state of the *Pacific Decadal Oscillation (PDO)* is useful for drought prediction. The PDO – movement of warm and cool water masses around the North Pacific – operates on decadal time scales which are likely closely related to or even driven by the three-to-five-year ENSO cycle in the tropical Pacific. Both independent and joint analyses of the PDO and ENSO are used to understand drought trends. Warm sea surface temperatures in the eastern North Pacific (positive PDO) shift storm track positions, leading to a drier Pacific Northwest during winter. East of the Rockies, the PDO's interactions with ENSO cycles result in noticeable rainfall variability. Particularly dry winter conditions, for example, occur when La Niña and positive PDO phases coincide, as well as when neutral ENSO and negative PDO phases coincide. Winter precipitation in Northern Texas, one of the regions hit hardest by the recent drought, is strongly influenced by PDO/ENSO interactions.



Above: The optimal tropical sea surface temperature anomalies for drought in corresponding regions in North America (red areas are warmer than average, blue are cooler). Image: Shin et al, 2010.

Land-Surface Conditions: While sea-surface temperature variability can explain much of the drought conditions that occur in North America, land-surface conditions can be another important driver. The Dust Bowl of the 1930s in the Central United States was likely exacerbated by farming practices. An initial drying, likely caused by sea surface temperature shifts, created a layer of dust on the topsoil which easily blew away. This led to an increased aerosol load in the sky over the Great Plains, which reduced surface radiation, convective heating and convective rainfall – an important source of moisture for the region, particularly during the summer months. Lack of convective rainfall led to further drying, more dust and even less rainfall: a "self-reinforcing" or "vicious" cycle.

Drought itself can be considered a "vicious" cycle. Less rainfall means drier soil conditions; drier soil conditions mean less evaporation and less rainfall. More rainfall means wetter soil conditions, more evaporation and more rainfall. These self-reinforcing processes lead to the existence of wet spells and dry spells. Vegetation also plays an important role in drought dynamics for similar reasons. In wet climates, particularly wet years stimulate plant growth. More plants mean more movement of moisture from the soil to the atmosphere, leading to more rain. Dry years generally mean less plant growth, less moisture movement and less rain. Dry years following wet years tend to be not quite as dry as they would be without plants. Plants help moderate year-to-year rainfall variations.

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