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Drought in New Mexico: History, Causes, and Future Prospects

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Drought in New Mexico: History, Causes, and Future Prospects

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Ecosystems and human societies have adapted to New Mexico's desert climate. During prolonged drought periods, however, life in the desert can become extraordinarily harsh and difficult. Drought in New Mexico causes dry riverbeds, widespread plant and wildlife mortality, failed crops, and may have contributed to the collapse of prehistoric civilizations in the not-so-distant past. It behooves us to study the history of drought to get an idea of what is in store for us when the next major drought event befalls us.

We don't have a thorough understanding of what causes long-term drought episodes. Recent research on the variability of the world's oceans offers insights into possible causes of drought, but our limited knowledge is not yet sufficient to provide reliable forecasts of when the next huge drought will occur, or (perhaps more importantly) to predict when an existing drought might end. As we will discuss, however, there are ominous signs that the current dry conditions may not abate soon and that New Mexico could be in for dry times for the next few years.

DROUGHT INDICES

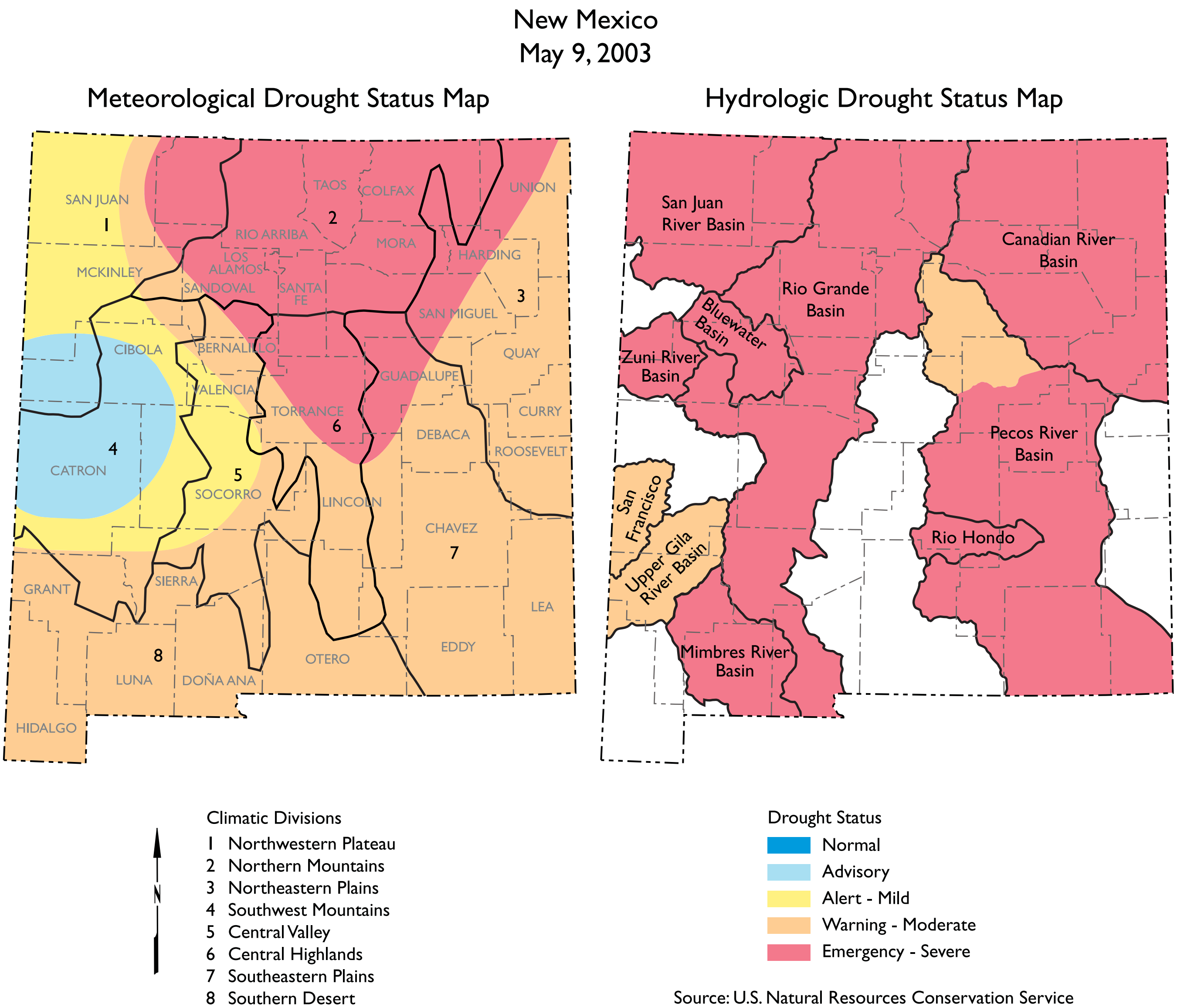
There is no standard quantitative or legal definition of "drought." The term refers to an extended period of time of below-normal precipitation, generally long enough to have pronounced effects on plants, rivers, or reservoirs. Thus, drought refers not just to persistent dry weather, but also to the various impacts that go along with dry weather. These impacts vary regionally. Three weeks without rain in a desert, coniferous forest, or wheat-growing region would have different effects in different seasons; they would have quite different consequences in a place that depends on precipitation replenishing a local reservoir than they would on a major, snow-fed river in a different location.

The National Drought Mitigation Center at the University of Nebraska defines three different "types" of drought: *meteorological* drought, defined strictly in terms of less than normal precipitation; *agricultural* drought, defined in terms of water-stressed crops or rangeland and anomalously dry soil; and *hydrologic* drought, measured in terms of shortages of surface water supplies (low reservoir levels and/or diminished stream flow). Meteorological drought affects ecosystems and economic activities that depend directly on local precipitation. Forested hillslopes, non-irrigated agriculture, and landscape watering in cities are examples. Agricultural drought generally refers to longer time scales than meteorological drought. Hydrologic drought affects large-scale waterworks and river flows, taking into account factors such as reservoir levels (which are affected by consecutive years of drought) and winter snowpack at the headwaters of large river drainages.

At present (June 2003) most of New Mexico has received near-normal precipitation for the water year that began in October 2002, hence in a formal sense we are not suffering from short-term meteorological drought. The Palmer Drought Severity Index, probably the single most commonly cited measure of drought conditions, is currently near zero (i.e., normal conditions) across most of New Mexico.

However, the Palmer Index is based entirely on local weather history. Dry conditions prevailed for several years before last autumn, and neither rangelands nor reservoirs have recovered from very poor conditions. Thus, indices of agricultural drought (such as soil moisture estimates) or hydrological drought (such as reservoir levels) indicate that New Mexico is deep in a long-term drought.

Recognizing the multiple components of drought, in spring 2003 the New Mexico Drought Task Force (which reports to the governor) switched from using the Palmer Index as its principal drought indicator to a two-component set of maps on the next page. The task force regards parts of the state to be in the midst of a long-term meteorological drought (the map on the left), emphasizing the multi-year precipitation deficit that has built up since the late 1990s. The map on the right shows the absolutely dire situation in the state with regard to hydrological drought in both the Rio Grande and Pecos drainage basins. Reservoir levels are very low (as a result of very dry years in 2001 and 2002), and current forecasts call for minimal river flows in the Rio Grande and Pecos River following a deficient winter snowpack in northern New Mexico and southern Colorado.

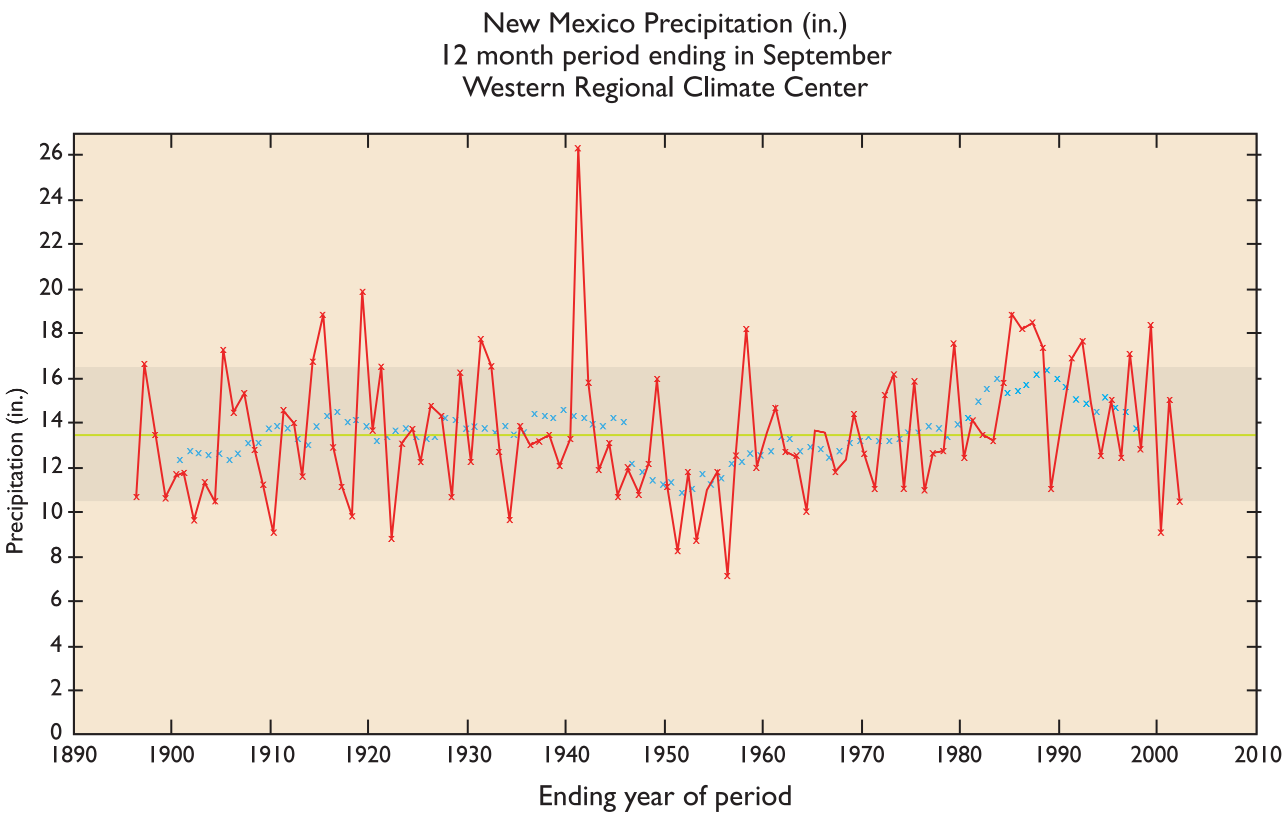


Drought status maps (issued May 9, 2003) from the New Mexico State Drought Task Force, available online from the New Mexico Climate Center at http://weather.nmsu.edu/drought/ (a) Status of "meteorological drought"; (b) Status of "hydrological drought." Color scheme is the same in both maps, ranging from blue ("normal" or no drought) to deep red ("emergency" or severe drought). Hydrologic drought is defined only for selected river basins; areas between these basins are left blank.

PREVIOUS DROUGHTS IN NEW MEXICO

Instrumental precipitation records in New Mexico extend back to the nineteenth century. A time series of annual precipitation averaged over the entire state since 1896, shown in the figure on the opposite page, is based primarily on a network of several hundred volunteer "cooperative observers" spread throughout the state organized by the U.S. National Weather Service. (Even today this network of citizens—ranchers, park rangers, backyard weather enthusiasts, etc.—none of whom receives payment for this effort—forms the backbone of our nationwide climate observing system.) Each annual value contains considerable uncertainty: there are large gaps between weather stations, and high mountain regions are undersampled, so the data in this figure probably underestimate the "true" statewide average. The solid green line shows the century-average annual precipitation in the state, about 13.5 inches.

Large inter-annual fluctuations of precipitation occur routinely. However the severe drought of the



Time series of annual water-year (October–September) precipitation averaged across New Mexico from 1896 to 2002. Red line shows annual data points; blue x's show 10-year running average; yellow line shows average annual precipitation for the entire period of record. Data and plotting routine are available online from the Western Regional Climate Center at http://www.wrcc.dri.edu

1950s clearly stands out as something unique in the twentieth century. For seven consecutive years, 1950–1956, annual precipitation was less than 12 inches. In three of those years (1951, 1953, 1956) the annual value was less than 9 inches, an amount lower than any year in the half century since then (although 2001 came close).

The 1980s and 1990s were years of plentiful rainfall by comparison. Precipitation failed to exceed 12 inches only one year in those two decades. These were decades of explosive population growth in the state. It is imperative for policy makers to understand that recent climatic conditions in the 1980s and 1990s were not "normal" by any standard. The 1980s and 1990s were just as anomalously wet as the 1950s were anomalously dry.

To put the drought of the 1950s and the wet spell of the 1980s and 1990s into long-term perspective, plots like the figure on this page can be extended backward in time using biological or geological indices that are known to correlate with climate in recent data. The most common such proxies for continental climate variability of the last 1,000–2,000 years are the annual growth rings in old trees, analyzed using a technique called dendrochronology. Trees in New Mexico have yielded a wealth of information on droughts and wet spells during the past millennium.

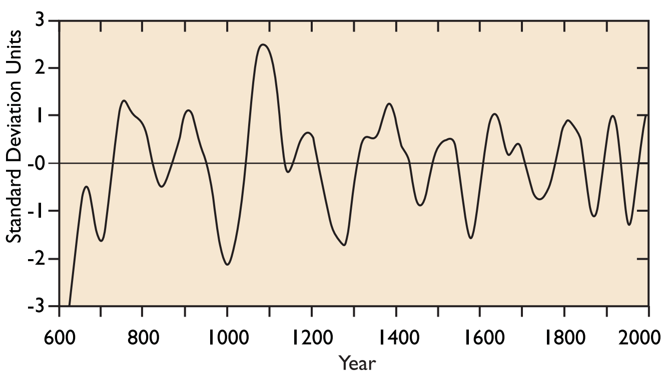
The dendrochronological record shown on the next page, for the period from A.D. 622 to 1994, is from a set of trees in south-central New Mexico. The graph shows the time series of reconstructed annual precipitation anomalies after a low-frequency smoother has been applied to emphasize long-period fluctuations, so short-term (one- or two-year) dry or wet spells are smoothed out. Several features are worth emphasizing:

- The 1950s drought was very substantial, but previous droughts (e.g., around A.D. 1000 and in the late thirteenth and sixteenth centuries) were both longer and drier.
- The late twentieth century wet spell is truncated by the smoothing function, but it is clearly a wet spell of historic proportions.

- Frequency analysis of this curve indicates that severe droughts occur at least once every century, with an average of approximately 60–80 years between droughts. An average drought periodicity between 50 and 100 years is observed in similar records throughout the Mountain West, suggesting that the next severe drought episode in New Mexico is due anytime within the next couple of decades.

CAUSES OF MULTI-YEAR CLIMATE ANOMALIES

What could cause precipitation to remain lower than normal for months, years, or a decade or more? The dendrochronological record shows that droughts have occurred in New Mexico for centuries, long before people were plentiful enough to disrupt the climate system. Research during the past several decades has



Reconstructed precipitation in south-central New Mexico, A.D. 622–1994, derived from tree ring records obtained in the Magdalena, San Mateo, and Organ Mountains. The annual precipitation values have been smoothed to emphasize multi-decadal fluctuations. From Grissino-Mayer, H., C.H. Baisan, and T.W. Swetnam, 1997, *A 1,373 year reconstruction of annual precipitation for the southern Rio Grande basin*: Final report for the Legacy Program.

pointed to slow variations in ocean temperature and currents, especially in the Pacific Ocean, as a major cause of wintertime climate variability across North America. The causes of prolonged summer droughts are not well understood at this time, but severe long-term winter droughts seem to span the seasons.

The El Niño cycle is the best known, and best understood, oceanic phenomenon that modulates drought in New Mexico. El Niño is an enormous tongue of anomalously warm Pacific Ocean surface water extending along the equator westward from the South American coast. The mirror-image cold phase is typically called La Niña. The cycle is not periodic, but extreme warm and cold phases each tend to occur several years per decade, reaching maximum amplitude in the Northern Hemisphere winter season.

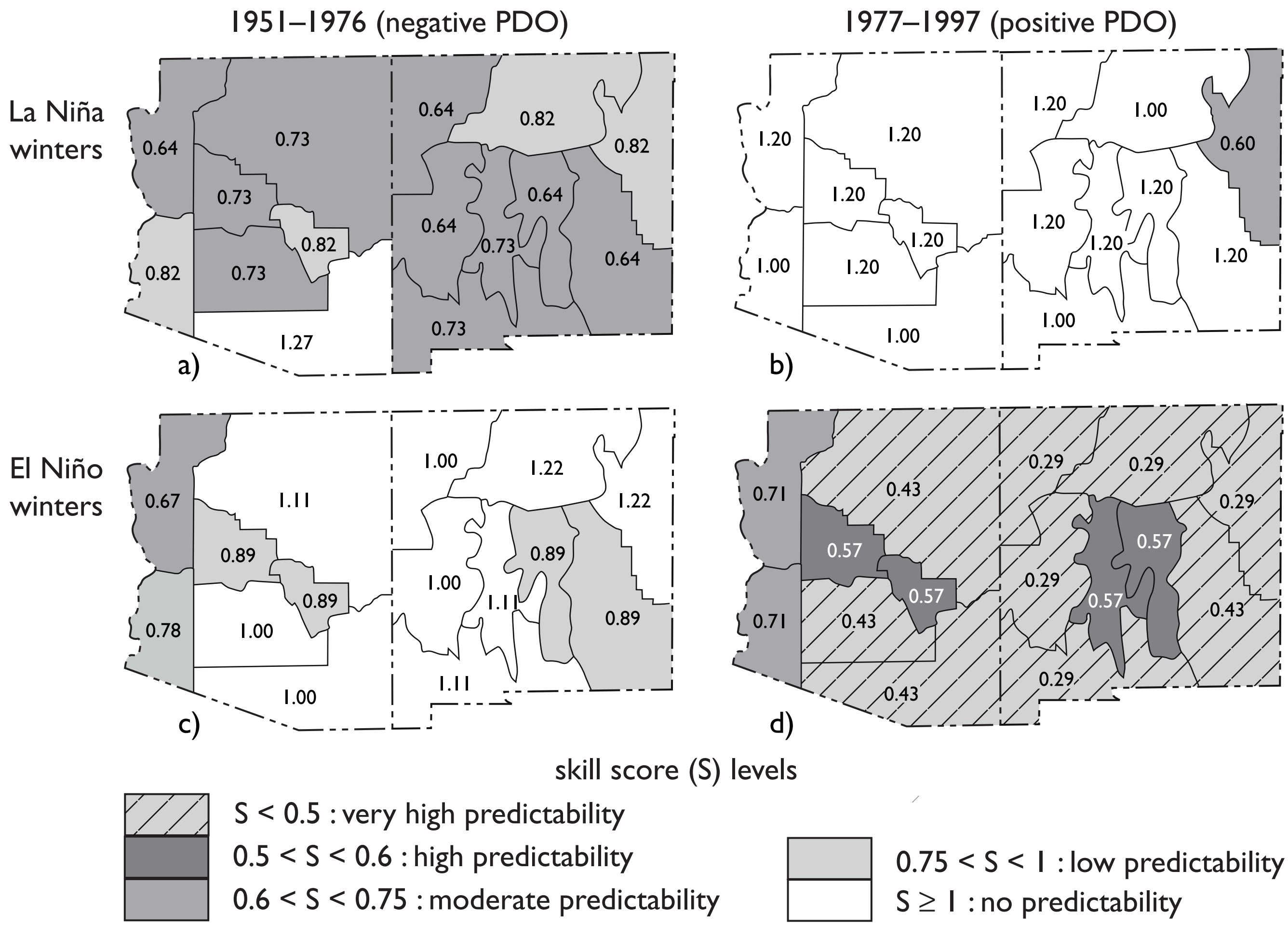
El Niño affects winter and spring precipitation by influencing the atmospheric jet stream across the Pacific Ocean. El Niño pulls the Pacific jet stream, and the storms that spawn off it, southward toward California and the southern U.S. Thus New Mexico tends to receive more precipitation than normal during an El Niño winter. La Niña has the opposite effect, pushing the jet stream northward and leaving New Mexico drier than normal.

Recent research shows that longer multidecadal fluctuations in the North Pacific Ocean also affect precipitation across southwest North America. In particular, North Pacific Ocean temperatures seem to vary more slowly than El Niño-related anomalies. This "Pacific decadal oscillation" (or PDO) seems to modulate the effects of El Niño, such that in its negative phase the effects of La Niña are amplified and the effects of El Niño are suppressed, whereas in the PDO's positive phase the opposite modulation occurs. The PDO was in a negative phase during the 1950s (when persistent drought plagued New Mexico), then abruptly flipped in 1977 so that the wet decades of the 1980s and 1990s took place during a PDO-positive period.

El Niño / La Niña extrema are the principal source of skill for current seasonal forecasts. When we see El Niño or La Niña forming in the summer and autumn we can be nearly certain that the ocean anomalies will persist through the winter. The PDO is currently not predictable, but it appears to have flipped back to a negative phase following the huge El Niño event of 1997–98. This ominous development may have contributed to the failure of last winter's El Niño event to generate abundant snowpack and break the current drought. Major research initiatives now in progress seek to gain better understanding of El Niño and PDO variability with the aim of improving long-range predictions of continental climate a year or more in advance.

CURRENT STATUS OF DROUGHT: SUMMER 2003

At the time this chapter is being written (June 2003) New Mexico is poised on the cusp of what could become the worst drought since the 1950s. Reservoir levels, streamflows, and rangeland-quality indices all indicate that the state is deep in agricultural and hydrological drought already. Unfortunately, current Pacific Ocean conditions are consistent with continuation of



Predictability of winter precipitation across Arizona and New Mexico derived from knowledge of El Niño or La Niña conditions the previous autumn (Gutzler et al., 2002). The plotted values represent a statistical measure of predictive skill, with 0 representing perfect predictability and 1 or greater representing no predictive skill at all. The top row of maps (maps a,b) show predictive skill associated with La Niña; the bottom row (c,d) depicts predictive skill associated with El Niño. The left column (a,c) is based on years between 1951 and 1976, when the PDO was in its negative phase. The right column (b,d) is based on years between 1977 and 1997 during a positive phase of the PDO. Thus La Niña effects (dry winters) were enhanced in the earlier period (a), and El Niño effects (wet winters) were enhanced in the later period (d). Pacific Ocean data since 1998 suggest that the PDO may have flipped back into its negative phase, whence the Southwest could be especially vulnerable to dry La Niña winters. From Gutzler, D., D. Kann, and C. Thornbrugh, 2002: Modulation of ENSO-based long-lead outlooks of Southwest U.S. winter precipitation by the Pacific Decadal Osicillation, Weather and Forecasting, vol. 17, pg. 1163–1172.

drought in New Mexico: Initial hints of the next La Niña event have been observed in the tropical Pacific, and the Pacific Decadal Oscillation seems to have shifted back into the phase that reinforces La Niña when it next occurs. Decision makers should anticipate the increasing likelihood that drought conditions in New Mexico will get worse in the near future.

SUGGESTED READING

Wilhite, D., editor, 2000, Drought—A global assessment (in 2 volumes): New York, Routledge.