Characterizing U.S. Drought over the Past Twenty Years using the U.S. Drought Monitor

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Abstract

One of the challenges of evaluating droughts in the context of climate change and linking these droughts to adverse societal outcomes is a lack of a uniform definition that identifies drought conditions at a location and time. The U.S. Drought Monitor (USDM), created in 1999, is a well-established composite index that combines drought indicators across the hydrological cycle (i.e., meteorological to hydrological) with information from local experts. This makes the USDM one of the most holistic measures for evaluating past drought conditions across the United States. In this study, the USDM was used to define drought events as consecutive periods in time where the USDM status met or exceeded D1 conditions over the past 20 years. This analysis was applied to 5km grid cells covering the U.S. and Puerto Rico to characterize the frequency of occurrence, duration, and intensification rates of drought, and the timing of onset, amelioration, and other measures for every drought event on record. Results from this analysis revealed stark contrasts in the evolution of drought across the United States. Over the western United States, droughts evolved much slower, resulting in longer-lasting but fewer droughts. The eastern United States experienced more frequent, shorter-duration events. Given the slower evolution from onset to drought peak, flash droughts were less common across the western United States, with a greater frequency over the southern United States. The most severe drought event on record was the 2012 drought, when more than 21% of the United States experienced its largest number of weeks at or above extreme (D3) drought conditions. It is expected that the availability of historical drought events would support future societal impacts studies relating drought to adverse outcomes and aid in the evaluation of mitigation strategies by providing a dataset to local decision makers to compare and evaluate past droughts.

Introduction

Drought is a natural and complex phenomenon that is defined as a reduction of moisture within the hydrological cycle that, over time, can have wide-ranging and cascading societal effects on agriculture, water quality, industry, and human health (Heim 2002; Sugg et al. 2020; Riebsame et al. 1991; Wilhite 2000). In the United States (U.S.), 18 of the past 20 years have had drought-induced agricultural losses (i.e., crop yields and livestock) exceeding a billion dollars, with an adjusted average loss of $6.97 billion and 26 heat stress-related deaths per year (NOAA 2021). In addition, there are well-known drought impacts on forest fire fuel and combustibility that influence not only the acreage burned, but also the intensity, severity, and frequency of forest fires (Littell et al. 2016). However, there are less well understood impacts of drought on water quality (i.e., harmful algae blooms), human health (i.e., Valley Fever, Lyme disease) and critical infrastructure (i.e., electrical grid, industrial productivity) that can result in secondary or indirect societal impacts, such as the loss of electricity service. These impacts are only expected to worsen as populations in water-limited environments continue to grow and the demand for water from energy, industry, and agriculture (i.e., demand from aquifers) expands (Mishra and Singh 2010). When combined with expected anthropogenic changes in climate, which can exacerbate drought conditions, the proportion of society vulnerable to drought is likely to increase over time.

Since droughts are not a preventable phenomenon, efforts to reduce societal impacts of drought have focused mostly on the development of mitigation plans that, when implemented, improve a region's resilience to drought. One of the challenges of developing successful mitigation strategies is that drought impacts can vary by drought event due to regional, seasonal, the timing of onset, severity, and the rate of intensification (i.e., flash droughts) among other factors. Therefore, successful mitigation strategies are often best developed locally through interactions and coordination between local, state, regional, and national stakeholders and governments (Smith et al. 2016), which allow these plans to prioritize key infrastructure and focus on communities most vulnerable to drought.

Mitigation and planning efforts can be greatly benefited by a national assessment of recent historical drought conditions (Mishra and Singh 2010) that identifies (i.e., beginning and end of each event) and characterizes (i.e., drought severity, intensification rate, longevity, seasonality) drought episodes at local scales across the U.S. (Askarimarnani et al. 2020). Asong et al. (2018) evaluated historical drought patterns across Canada using the Standardized Precipitation Evapotranspiration Index (SPEI; Vicente-Serrano et al. 2010), in part to improve efforts at developing sustainable water management planning. While Asong et al. (2018) chose to use SPEI, there are a number of possible drought indices (Heim 2002; Zargar et al. 2011) that span the range of the hydrological cycle from precipitation (i.e., Standardized Precipitation Index; McKee et al. 1993, SPI), estimates of soil moisture conditions (i.e., PDSI; Palmer 1965), and evaporation deficits (i.e., Evaporative Drought Demand Index (EDDI); Hobbins et al. 2016, Vegetation Drought Response Index; Brown et al. 2008) to stream flow and reservoir levels (i.e., Surface Water Supply Index; Shafer and Dezman 1982). The choice of the most appropriate index from which to evaluate historical drought events will depend on the specific impact of interest and the availability of data used to derive the drought metric in addition to spatial extent, temporal availability, scientific clarity, and other aspects (Steinemann et al. 2006). However, it may not always be clear which drought metric or set of metrics best align with specific drought impacts (e.g., human health, infrastructure). In these situations, composite indices that combine moisture conditions from multiple indices may be more beneficial to the broader community than a single drought metric.

The U.S. Drought Monitor (USDM), which was established in 1999, blends information from drought indicators from across the hydrological cycle with information from local experts (Svoboda et al. 2002). This integrated approach makes the USDM one of the most holistic measures of drought conditions across the U.S., Puerto Rico, U.S. Virgin Islands, and U.S. Affiliated Pacific Islands. The purpose of this study is to define and characterize the climatology of U.S. drought conditions from 2000–2019 from weekly USDM maps. This paper will identify important regional differences in drought formation and evolution, and produce a localized assessment of the timing, duration, and intensity of all past drought events. It is anticipated that a historical analysis or identification of unique drought episodes will not only be useful in evaluating current and future hydrological indicators and seasonal drought forecasts, but also in establishing links between specific drought events and their respective impacts on society.

Data

The USDM is produced through a collaborative effort of the National Drought Mitigation Center (NDMC), U.S. Department of Agriculture (USDA), National Oceanic and Atmospheric Administration (NOAA), and local experts (Svoboda et al. 2002). Using geophysical observations (e.g., precipitation, temperature, stream flow, soil moisture, vegetation state, and others) and information from local experts from the field, the USDM authors have generated weekly evaluations of drought conditions across the U.S. operationally since January 4, 2000. Drought authors combine this information, which is presented in percentile rankings, to form a composite index that categorizes conditions into six levels of severity ranging from no drought (None) to exceptional (D4) drought (Table 1).

A gridded 5 km daily precipitation dataset based on the Global Historical Climatology Network (GHCN; Menne et al. 2012) was used to evaluate precipitation conditions during phases of drought intensification and amelioration. The daily version of the gridded dataset referred to as nClimGrid-d contains spatially interpolated station observations of temperature and precipitation from GHCN (Vose et al. 2014) between January 1, 1951 to present. For precipitation, only grids with measurable precipitation (greater than 0.1 mm) were spatially interpolated, with the daily sums forced to match monthly totals. More information about nClimGrid-d can be found from Vose et al. (2014), and the dataset is publicly available at https://www.ncei.noaa.gov/pub/data/daily-grids/.

Methods

The weekly drought maps from the USDM were placed on a 5-km-resolution grid that aligned with nClimGrid-d. To ensure the consistency of the resolution across higher-latitude grids in Alaska, the grid was created using an Albers Equal Area projection, resulting in 374,309 cells that span the USDM regions. For the 2000–2019 period, 1044 weekly files were placed on this grid to provide a high-spatial-resolution dataset from which to define and characterize drought events across the U.S. The weekly USDM gridded files used in this study are publicly available at https://www.ncei.noaa.gov/pub/data/nidis/geojson/us/usdm-tiff/albers-equal-area/.

A time series of weekly USDM drought status (Dx value) at each grid cell was generated from the gridded dataset and used to identify non-overlapping drought events, as outlined in Leeper et al. (2021). We defined a drought as beginning the first week the USDM status meets or exceeds moderate drought (D1) conditions and ends the last week the USDM status meets or exceeds D1, followed by three or more consecutive weeks of abnormally dry (D0) or None conditions (Fig. 1). This methodology identifies periods of time where the USDM denoted persistent drought conditions over a grid cell to form drought events. These drought events were then analyzed to evaluate the frequency and duration of drought episodes as well as the timing of onset and termination and the phases of drought intensification (from onset to the first week of peak drought status or onset peak) and amelioration (the last week of peak drought status or termination peak to drought termination). It should be noted here that not all drought events will have a maximum USDM status exceeding moderate drought (D1) conditions, which makes it challenging to identify the onset peak and termination peak weeks. In those cases, the drought events were excluded from analyses requiring onset and termination peak weeks, such as the median days from onset to onset peak or accumulated precipitation from termination peak to termination. Other analysis excluding D1 peak drought events include the median days from onset to onset peak and termination peak to termination. In addition, the U.S. Virgin Islands and U.S. Affiliated Pacific Islands were excluded from this analysis since they lacked the 20-year record of weekly drought maps; however, the document of historical drought events is available in these areas

Evaluations of precipitation conditions from nClimGrid-d during phases of intensification and amelioration were based on calculations of percent of normal precipitation (Eq. 1).

Eq. 1. $$\text{percent of normal} = \frac{eventPrecip}{historicalPrecip} * 100\%$$

For drought intensification, eventPrecip was the accumulated precipitation from onset to onset peak and historicalPrecip was the average accumulated precipitation over that same period from 1981 to 2010. Percent of normal precipitation over the amelioration phase was similarly calculated between termination peak and the week following termination to capture the final reduction in USDM drought status to abnormally dry (D0) conditions. From percent of normal, it is possible to assess if precipitation conditions were drier (< 100%) or wetter (> 100%) than usual for that location and time of year.

Results

During the 20-year period, drought events identified by the USDM were more frequent across the eastern half of the U.S. than the western half, with some of the highest event counts (+15) in the Southeast and southern Plains (Fig. 2). In addition to a west-to-east gradient in drought frequency, there were also fewer drought events north of Kentucky and Virginia (i.e., portions of Indiana, Ohio, Pennsylvania, New Jersey, Rhode Island, New York, Vermont, Connecticut, New Hampshire, and Maine), which suggest these areas have been largely spared from drought over the past 20 years. In Hawaii, topographical factors seem to have favored drought formation on the windward side of the island. A strong spatial gradient in drought-event duration (Fig. 3) was also captured, with the western half of the CONUS and Hawaii experiencing drought (D1 or greater) conditions for more than 40% of the time between 2000 and 2019. The USDM analysis indicates that drought has occurred infrequently in Alaska. However, this is believed to be the result of an evolving understanding of how drought indicators should be applied in higher-latitude environments when monitoring drought severity and its impacts (Bathke et al. 2019) rather than a lack of drought conditions.

The seasonality of drought onset and termination revealed drought across the U.S. was more spatially variable for drought onset than termination (Figs. 4 and 5). Over much of the interior United States and Alaska, drought events typically began over the summer (June, July, and August) and fall (September, October, and November) seasons. In the Alaska panhandle, drought onset primarily occurred over spring months, with winter being the most likely season for much of Washington and Oregon. Over the desert Southwest and the islands of Puerto Rico and Hawaii, seasonal onset was particularly variable. However, the seasonality of drought termination had less spatial variability where droughts typically ended in either the winter or fall seasons over much of the coastal western states and the summer months in the Desert Southwest. Spring termination was mostly confined to the interior portions of the United States with the exception of the Northeast, which tended to have fewer drought events over the past 20 years compared to the rest of the United States. In Alaska, there were sharp contrasts between the temperate rainforest of the panhandle and the rest of Alaska in the seasonality of termination. Similar to the season of onset, the tropical locations of Hawaii and Puerto Rico had a wide range of preferred drought termination, with nearly all four seasons represented.

Evaluations of median precipitation conditions during drought revealed much of the CONUS had drier than normal precipitation (less than 100%) as drought conditions intensified from onset to onset peak (Fig. 6). This was particularly true for much of Texas and Oklahoma, southern California, and the coastal areas of Oregon and Washington, where median precipitation conditions were less than 30% of normal. However, over elevated areas of the central West, conditions during the intensification phase were not as dry, with near-normal (70% to 100%) precipitation conditions. During the amelioration phase of drought from termination peak to termination, above-normal precipitation was predominant across the U.S., with some regions receiving up to six times (600%) normal precipitation (Fig. 7). Median precipitation conditions exceeding two times the normal precipitation (>= 200%) were found over the Ohio Valley, parts of the Midwest, Texas, and California, with near-normal precipitation conditions during drought amelioration over much of the northeastern U.S. The spatial variability of precipitation conditions during these critical phases of drought formation and termination was very regionalized and likely associated with the timing of drought onset and amelioration in relation to seasonal precipitation patterns, number of drought events, and rates of intensification and improvement.

Flash droughts are a special type of drought event characterized by rapid intensification (Otkin et al. 2018). While the exact definition of a flash drought is still being debated in the literature (Chen et al. 2019, Otkin et al. 2018), in this analysis, flash drought was defined as degradations in USDM status of three or more categories over a five-week moving window, which allows for the maximum-possible rate of change (five categorical changes from None to D4 in a five-week period) to be reported. In addition, there was no requirement for the rapid intensification to occur during drought onset; however, the likelihood of meeting the three-status change requirement would be higher during the earlier stages of drought formation. In this analysis, flash droughts were more likely to occur east of the Rockies, with a greater frequency over southern U.S. States, excluding Florida (Fig. 8).

To further evaluate rates of intensification and abatement, the number of median weeks from drought onset (D1) to peak onset (Fig. 9) and termination peak to termination (Fig. 10) were analyzed. These results illustrate that rates of drought intensification and abatement were much slower over the western third of the U.S. compared to the eastern two-thirds. The slower rates of drought change across the U.S. explain why flash droughts were rare across western portions of the U.S.

Assessments of drought severity revealed that western states have not only spent more time in drought than eastern states (Fig. 3), but also have spent more time in Extreme Drought (D3) or greater (Fig. 11) conditions. Portions of the U.S. that have spent up to two years in D3 or greater drought extend from parts of California over the Rockies and into New Mexico, Texas, and the Oklahoma panhandle. This diminishes to less than a year for most of the eastern U.S., with an exception of Georgia and portions of Alabama and the Carolinas, which had up to a year in D3 or greater conditions from 2000 to 2019. In comparison, D3 or greater status was rare over parts of the Great Lakes, Ohio Valley, and Northeast, which suggests these regions have been largely spared from severe drought conditions over the past 20 years.

To explore some of the more noteworthy drought events to have impacted the U.S. over the past 20 years, plots of the starting year for the most intense (most weeks at D3 or greater; Fig. 12) and longest-lasting (Fig. 13) events were generated. Figure 12 illustrates the footprint of the most severe drought events for every region of the U.S., including the 2012 drought over the central U.S.; the 2010–2011 event across parts of Arizona, New Mexico and Texas; and the 2012–2013 California drought. Over the Northeast, the most severe drought event was almost 20 years ago, in 2001. The western half of the main island of Hawaii had its most severe drought event in 2009. Of these severe drought events, the 2012 drought event stands out as representing the greatest area (number of grid cells) of the U.S. and Puerto Rico at 21.21%, followed by 2002 (14.81%), and 2001 (11.19%) rounding out the top three (Table 2). Assessments of the longest-lasting drought events (Fig. 13) show some differences over eastern Nevada and the central U.S. compared to the number of weeks greater than D3. However, there was little change in the area ranking among drought event start years (Table 3), apart from 2013 replacing 2007 in the top five. The spatial contrasts between these two measures suggests that the longest-lasting drought event may not always align with the event having the greatest number of weeks at D3 or greater conditions.

Discussion and Conclusions

There were strong spatial contrasts in drought frequency, duration, and intensity across the CONUS, Alaska, Hawaii, and to a lesser extent Puerto Rico. These spatial patterns in drought formation and evolution were mostly aligned with seasonal to interannual variations (i.e., ENSO, PDO, NAO, etc), topographic, and tropical cyclone variations in precipitation. For instance, in semiarid to arid regions of the U.S. (i.e., Western CONUS), precipitation is characterized by pronounced wet and dry seasons, such as the summer monsoon rains over the Desert Southwest and the wetter winters across the coastal West. Since it is not uncommon to have long periods (i.e., months) with little to no precipitation during the dry season, it can be challenging to identify emerging drought or improving drought conditions during these seasons. The lack of precipitation would also lead to drought persistence over the dry season, impacting both the longevity and intensity of drought since a previous week's drought status would likely persist into the following week.

Within the more humid climates east of the Rockies and in northeastern Hawaii, year-round precipitation reduces the opportunity for drought persistence since there is no dry season. However, when precipitation is suppressed, moisture deficits (i.e., precipitation and soil moisture) can quickly accumulate with respect to normal conditions, leading to rapid drought intensification and potentially flash droughts when combined with high rates of evaporative demand (Otkin et al. 2016, Otkin et al. 2019, Hobbins et al. 2016, and Basara et al. 2019), which was more prevalent in southern States. While there are subdued wet and dry seasonal cycles east of the Plains, there are important variations in the organization of (scattered versus widespread) precipitation events. For instance, convectively driven events such as sea breezes or pop-up showers that are most predominant during the warmth of summer and early fall can lead to localized precipitation that is still outpaced by evaporative demand from warmer temperatures and an active vegetation layer. In contrast, the more organized precipitation events along frontal boundaries and tropical cyclones for much of the Southeast and Puerto Rico can bring about widespread drought-relieving precipitation. It should be noted here that Puerto Rico and coastal areas of the U.S. that are dependent on tropical moisture may see drought formation in years when tropical activity is suppressed (i.e., La-Nina in the Atlantic Basin). Overall, the combination of year-round precipitation leads to more frequent, shorter-lived drought events that can develop rapidly.

In Alaska, the climate varies from a temperate rainforest in the panhandle (Bathke et al. 2019) to an arctic tundra in the northern and interior regions (mean annual precipitation between 115 to 270 mm; Arguez et al. 2010). The contrast between the panhandle and arctic tundra is particularly evident in drought onset and termination, where droughts in the Alaska panhandle typically begin and end in the spring, prior to the summer dry season. In northern and interior regions, moisture conditions (i.e., deficits) over the summer wet season get frozen in place during the long, cold, dry winter season, so summer and fall are typically the seasons when drought both begins and ends. Despite these contrasts, it should be noted here that assessments of drought severity over Alaska, particularly in polar regions, are challenged by two factors. The first is associated with the difficulty of monitoring drought impacts over areas with low population density, little agriculture, and poor communication networks (i.e., no internet, lack of power), which has limited access to updated information regarding drought conditions on the ground in the past. The second involves the use of hydrological indices that were developed and verified primarily for use over mid-latitudes. In many ways, our understanding of how drought manifests and how to monitor evolving conditions in near-real-time over northern-latitude regions is still developing and will require extensive outreach to local communities, which is currently ongoing.

In a similar way, the USDM status (Dx) determinations are also evolving nationally through the incorporation of new drought indicators, experiences from new drought authors identified via outreach efforts, and scientific research. These changes in status determinations can lead to important shifts in the temporal stability (i.e., percent of time in any drought status) of the USDM as well as its responsiveness to evolving drought conditions over time. These non-climatic changes in USDM conditions should be further explored alongside changes in precipitation patterns due to climatic change, which may alter precipitation and other hydrological measures (i.e., stream and reservoir levels, snowpack, and soil moisture) associated with specific Dx categories. Additional areas of intrigue include the development of regionally or seasonally based flash drought definitions that account for typical rates of intensification, or the influence of predominant drought type geographically (e.g., agricultural versus hydrologic). These and other analyses that combine more quantitative measures of drought conditions (i.e., SPEI, EDDI, etc.) can be further explored with this high-resolution USDM climatology and drought event dataset.

While the USDM period of record precludes some of the most severe drought episodes (based on measures of PDSI) over the early to mid 1900s (i.e., 1930s Dust Bowl and 1950s droughts; Heim 2017), it does capture more recent severe drought episodes such as the 2010–2011 Southwest/Texas drought (Nielsen-Gammon 2011), the 2012 drought over the central U.S. (Hoerling et al. 2014), and the long-lived 2013–2015 California drought (Mann and Gleick 2015). These more recent events may provide more relevant insight to drought mitigation and planning efforts than historical "droughts of record" that occurred in a different era of land-use management and other policies and regulations that alters a society's vulnerability to drought. Referring to more recent droughts, particularly ones that were characterized by a more comprehensive index such as the USDM, to develop mitigation and resilience strategies would better inform the planning process (Wilhite, 2000). For instance, a better understanding of the spatial and temporal aspects of drought, as well as how drought severity evolves during an event, can inform how drought is monitored and who needs to be involved in the planning process (and at what stage). Furthermore, documenting the frequency and severity of recent drought events may help planners justify the need for funding to develop, update, and evaluate current mitigation and resilience strategies going forward.

The impact of drought on society is a growing area of research that stands to benefit from the documentation of the frequency, timing, and intensity of recent drought events from a common frame work (Liu, et al. 2020). For instance, the impacts of drought on agriculture may have more to do with the timing of soil moisture deficits during the critical stages of plant development rather than drought severity. In a similar way, the longevity of drought events is an important component in the buildup of vegetation-based fuels for forest fires. This is particularly true in the subpolar regions of Alaska, where wildfires have become more frequent and intense (Bieniek et al. 2020). In terms of impacts perspective, two droughts with similar levels of intensity can have very different societal outcomes. Assessments of impacts can be further complicated when droughts are combined with other hazards, such as heat waves or drought-induced changes in pests (i.e., ticks) and fungal (i.e., vibro, coccidiomycosis) environments that increase human exposure, all of which lead to direct and indirect adverse outcomes on human health, infrastructure, and economic activity (Coopersmith et al. 2017). Many of these indirect outcomes are difficult to link with drought conditions without an accounting (i.e., time of onset and rates of intensification) of historical drought events. In addition, it may not be clear as to which hydrological indicator of drought (i.e., meteorological, agricultural, hydrologic, or ecological) would be most appropriate to link with specific impacts (i.e., human health or infrastructure). A USDM-based listing of prominent drought events would allow for direct comparisons of droughts that were more impactful for a specific outcome (i.e., hospitalization, agricultural yields) at a location. This allows decision makers and researchers to explore the relative importance of time, severity, duration, rates of intensification, and potentially other factors that distinguishes drought events from others that have impacted the same region with similar levels of intensity. In addition, a historical listing would facilitate the evaluation of drought mitigation strategies by comparing the impacts of drought (i.e., agricultural yields, hospitalization, water quality and availability, etc.) before and after the implementation of a mitigation strategy.

In this study of the USDM 20-year record, drought events were defined and analyzed to reveal differences in the formation and evolution of drought conditions across the U.S. and Puerto Rico. The USDM record is sufficiently long to support one of the first composite-based climatologies of drought that combines both hydrological indices and regional impact assessments of drought conditions from the field. This climatology, as presented in this paper, illustrates regional differences in drought frequency, duration, intensity, timing, and rapidity of development that have been related to regional differences in precipitation and other factors. Furthermore, it is hoped that a dataset of locally determined drought events that describe each drought episodes’ onset, termination, intensity, and rates of intensification among others would facilitate future drought impacts studies and improve efforts to build societal resilience to drought events.

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Data Availability: The drought status conditions that were gridded and used to define drought events were obtained from the National Drought Mitigation Center at the University of Nebraska, Lincoln, NE, (https://droughtmonitor.unl.edu/Data/GISData.aspx) as described by Svoboda et al. (2002). The gridded precipitation dataset from nClimGrid is publicly available at https://www.ncei.noaa.gov/pub/data/daily-grids/ with more information regarding the dataset available from Vose et al. (2014).

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Tables

Table 1. USDM categories and corresponding drought indicator percentiles.

Category	Description	Indicator Percentile Range
None	No drought or abnormal dryness	31 to 100
D0	Abnormally Dry	21 to 30
D1	Moderate Drought	11 to 20
D2	Severe Drought	6 to 10
D3	Extreme Drought	3 to 5
D4	Exceptional Drought	0 to 2

Table 2. The top five drought events having the most weeks at D3 or greater drought status over the U.S. and Puerto Rico.

Start Year	**Percent of Area**
2012	21.21%
2002	14.81%
2001	11.19%
2010	11.09%
2007	8.41%

Table 3. The top five longest-lasting droughts over the U.S. and Puerto Rico.

Start Year	**Percent of Area**
2012	18.72%
2001	12.58%
2002	11.38%
2010	9.99%
2013	7.98%

Figures

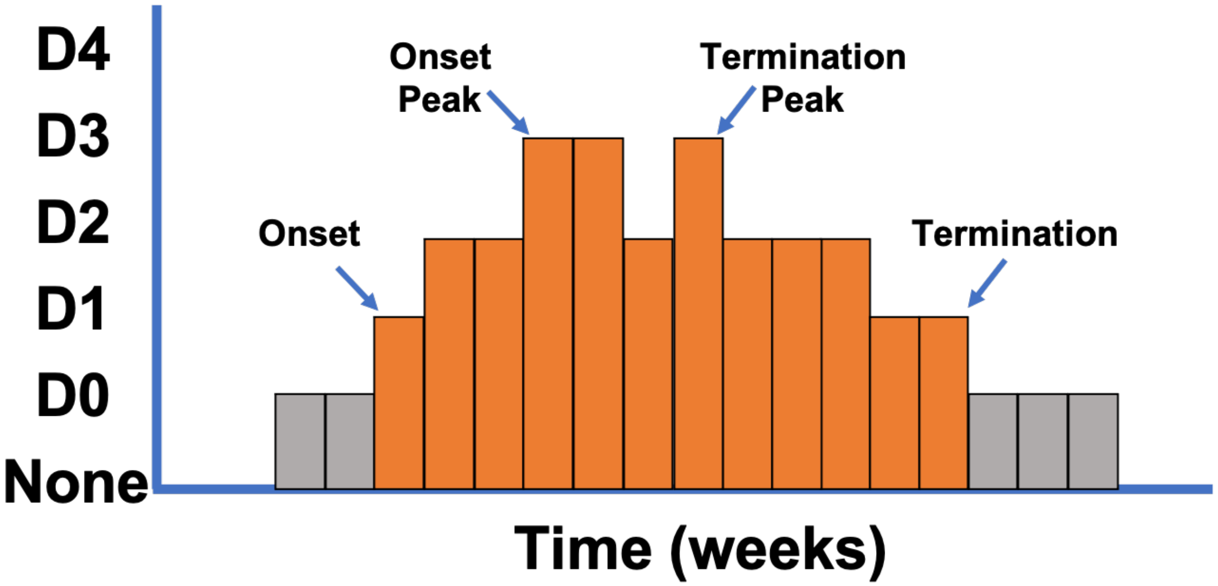

Fig 1. Schematic representation of a drought event (orange) with onset occurring the first week of D1 conditions, onset and termination peak defined as the first and last week of peak USDM status over the drought event, respectively, and drought termination defined as the last week of D1 conditions followed by three weeks or more of D0 or None status.

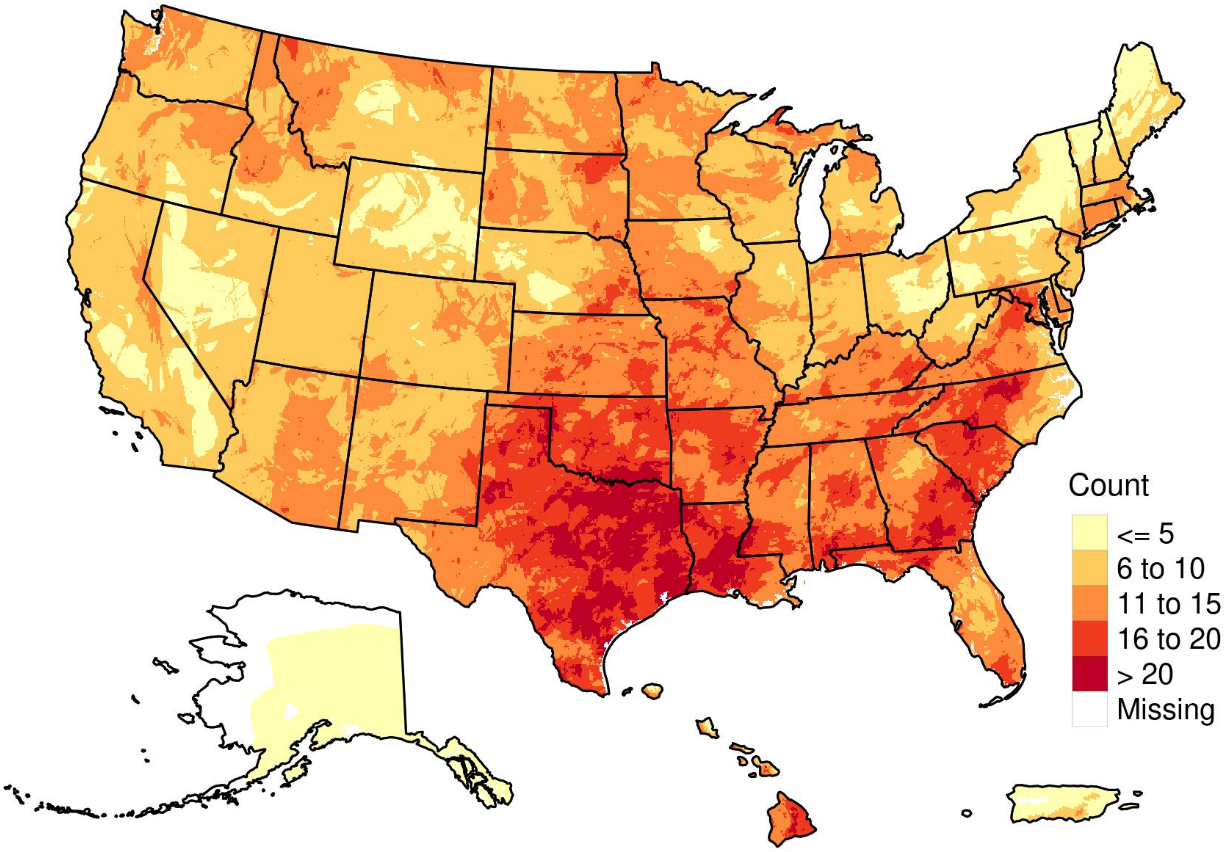

Fig. 2. Drought event counts from 2000 through 2019.

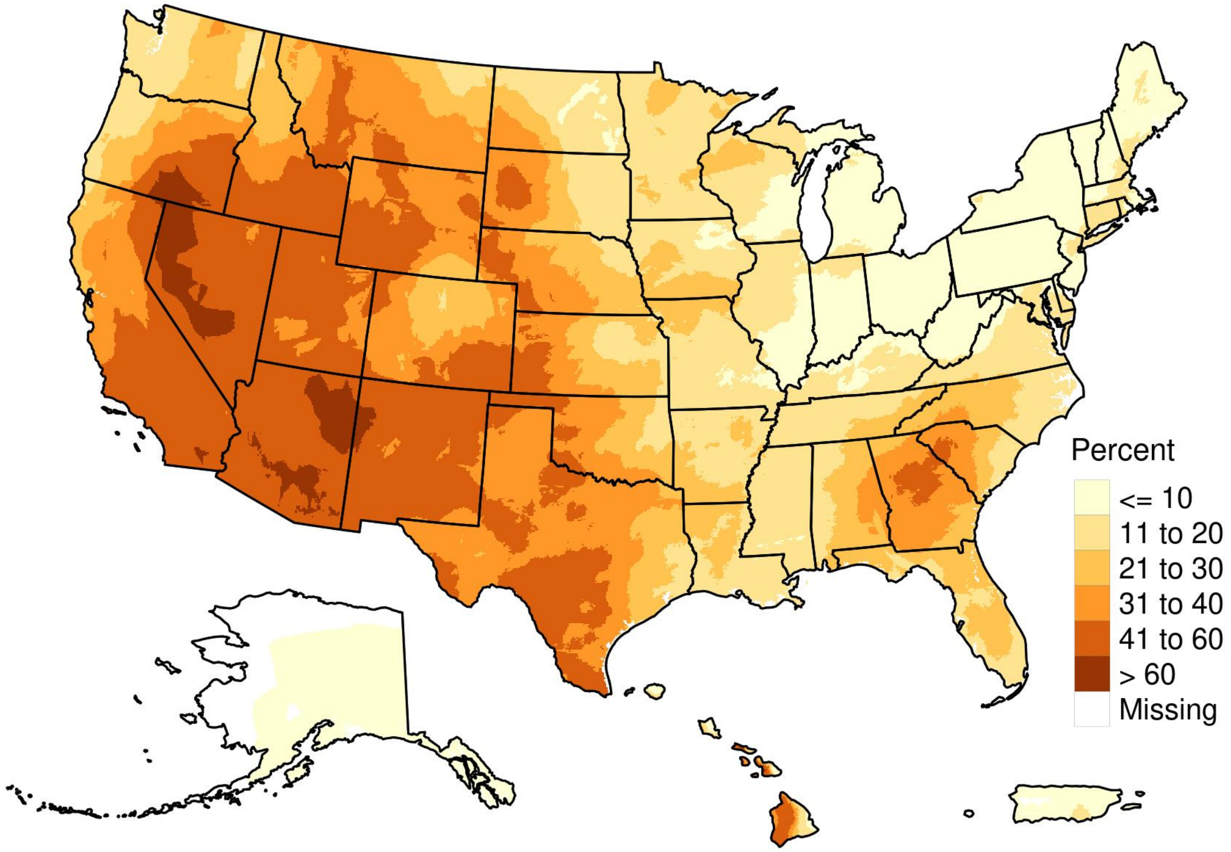

Fig. 3. Percent of time spent in D1 or greater drought status from 2000 through 2019.

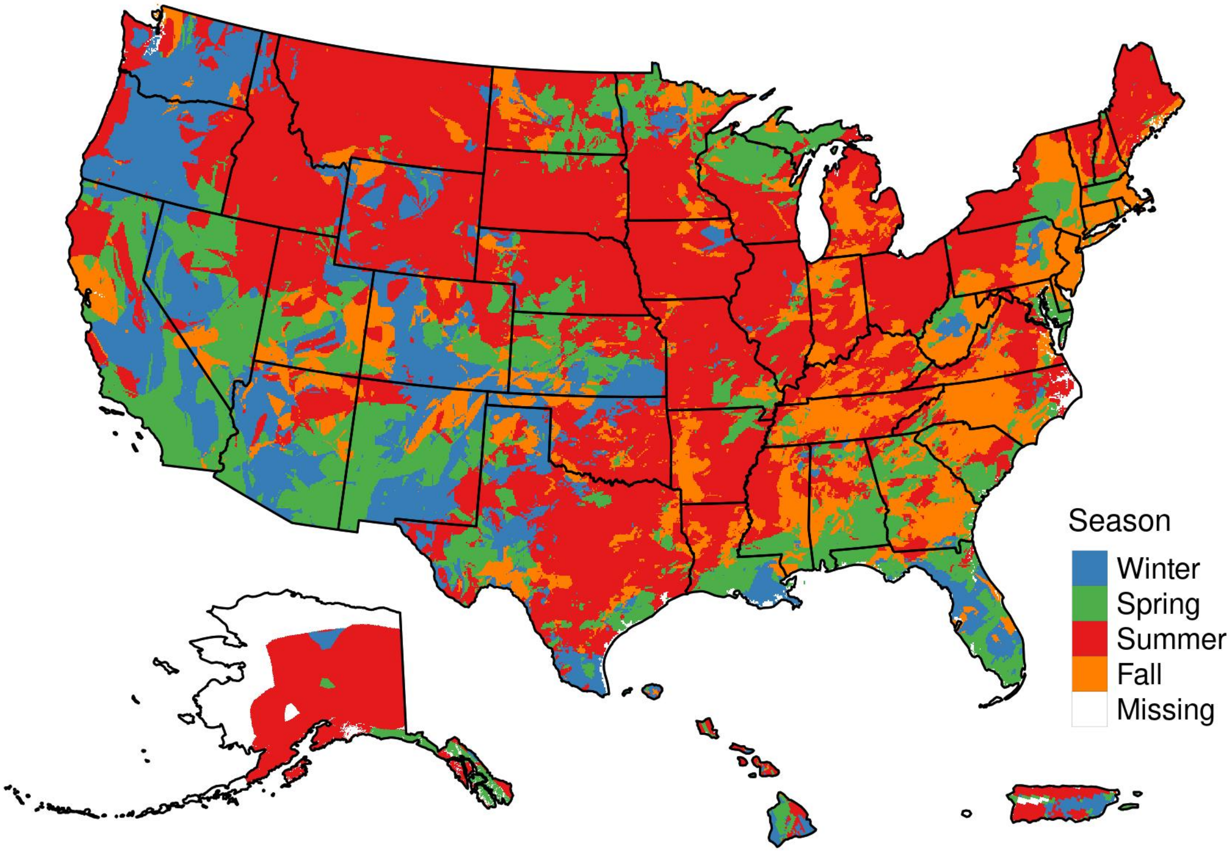

Fig. 4. The mode of seasonal drought onset for all drought events from 2000 through 2019.

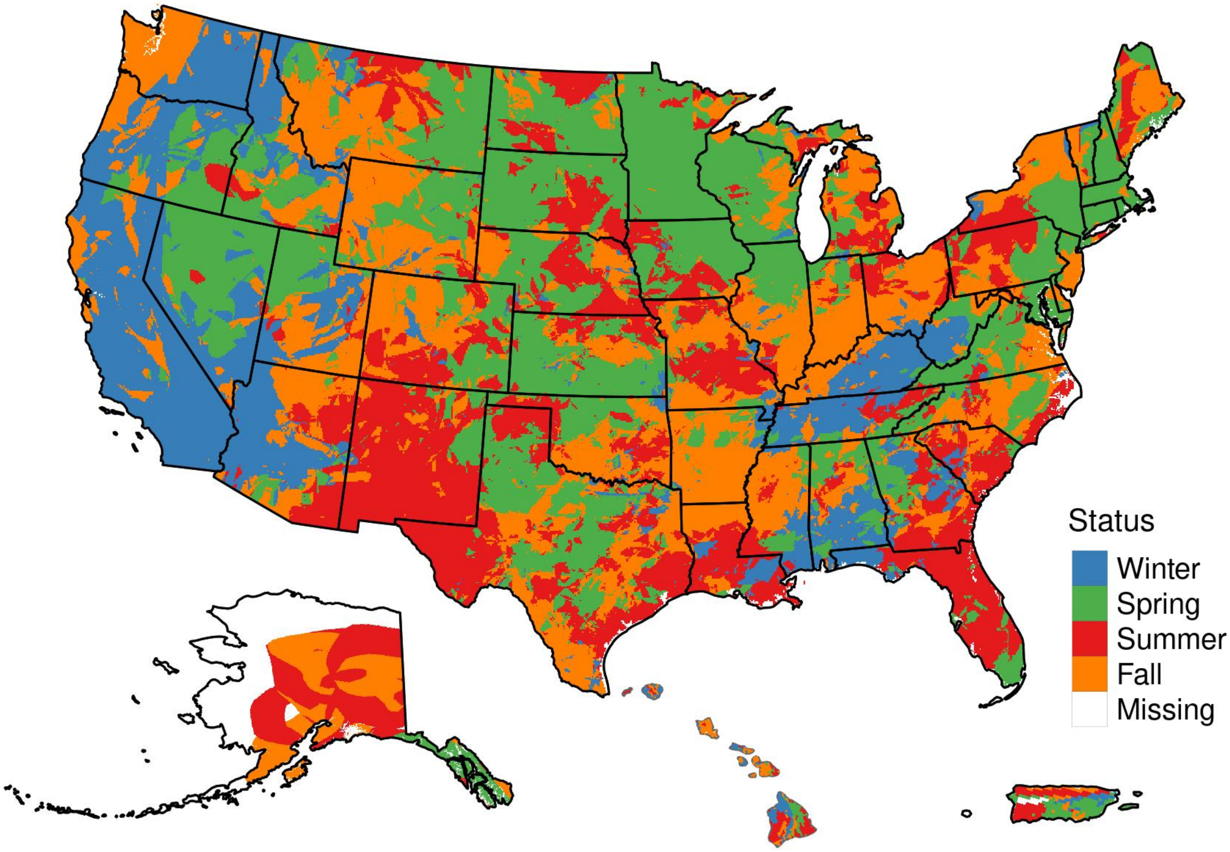

Fig. 5. The mode of seasonal drought termination for all drought events from 2000 through 2019.

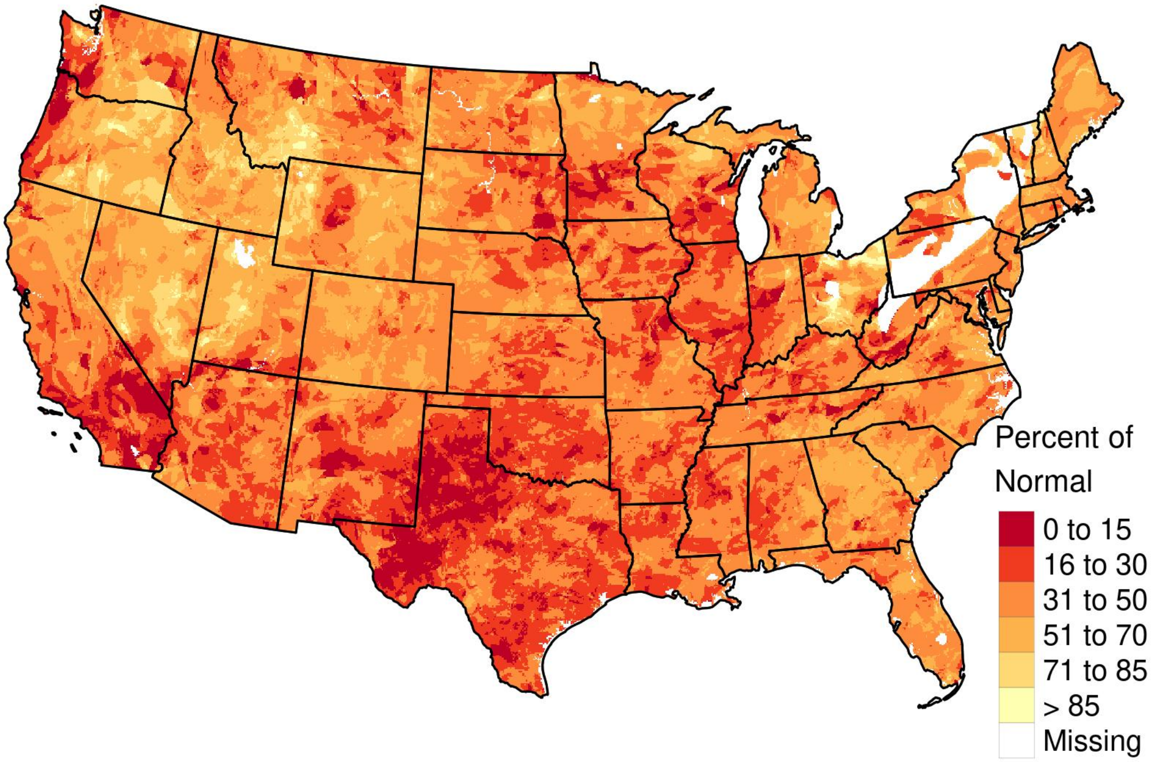

Fig. 6. Median percent of normal precipitation from drought onset to the peak onset. This analysis excluded drought events that had peak status conditions less than D2.

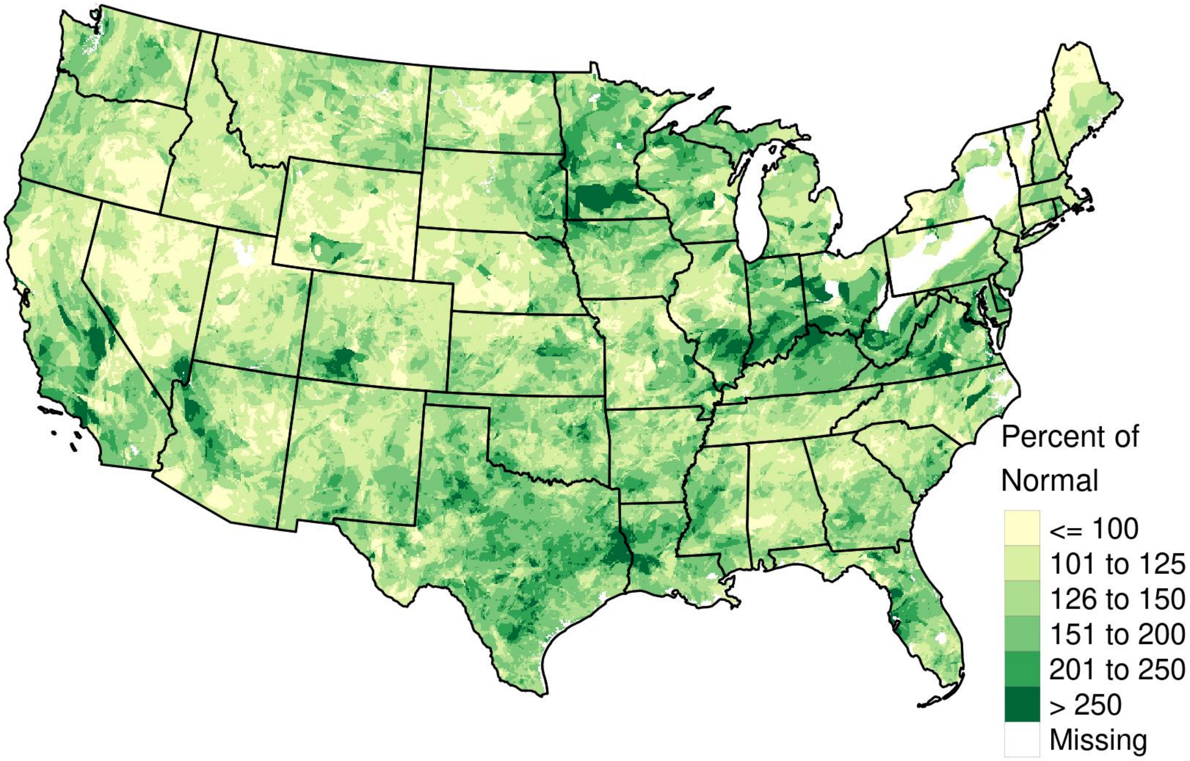

Fig. 7. Median percent of normal precipitation from termination peak to drought termination. This analysis excluded drought events that had peak status conditions less than D2.

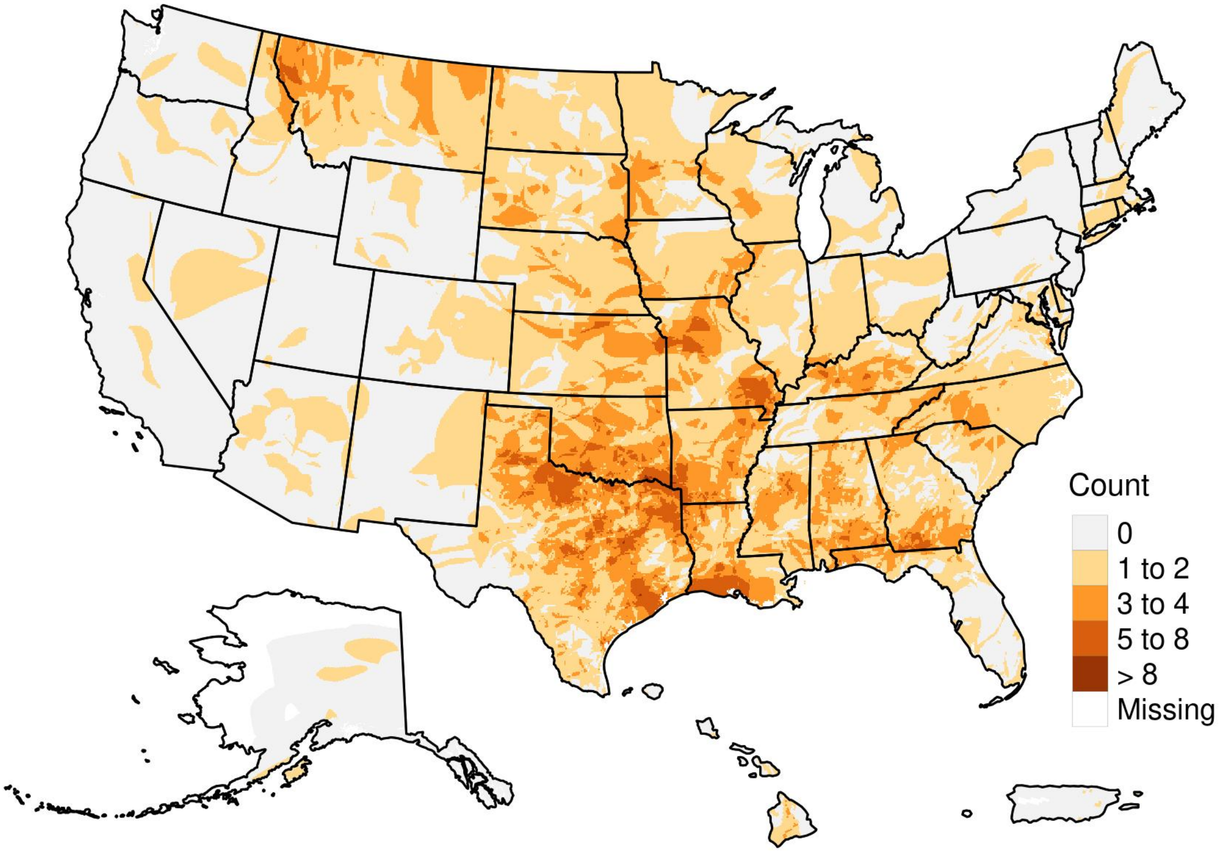

Fig. 8. The count of flash drought events where increases of three or more USDM statuses occurred within a five-week period from 2000 through 2019.

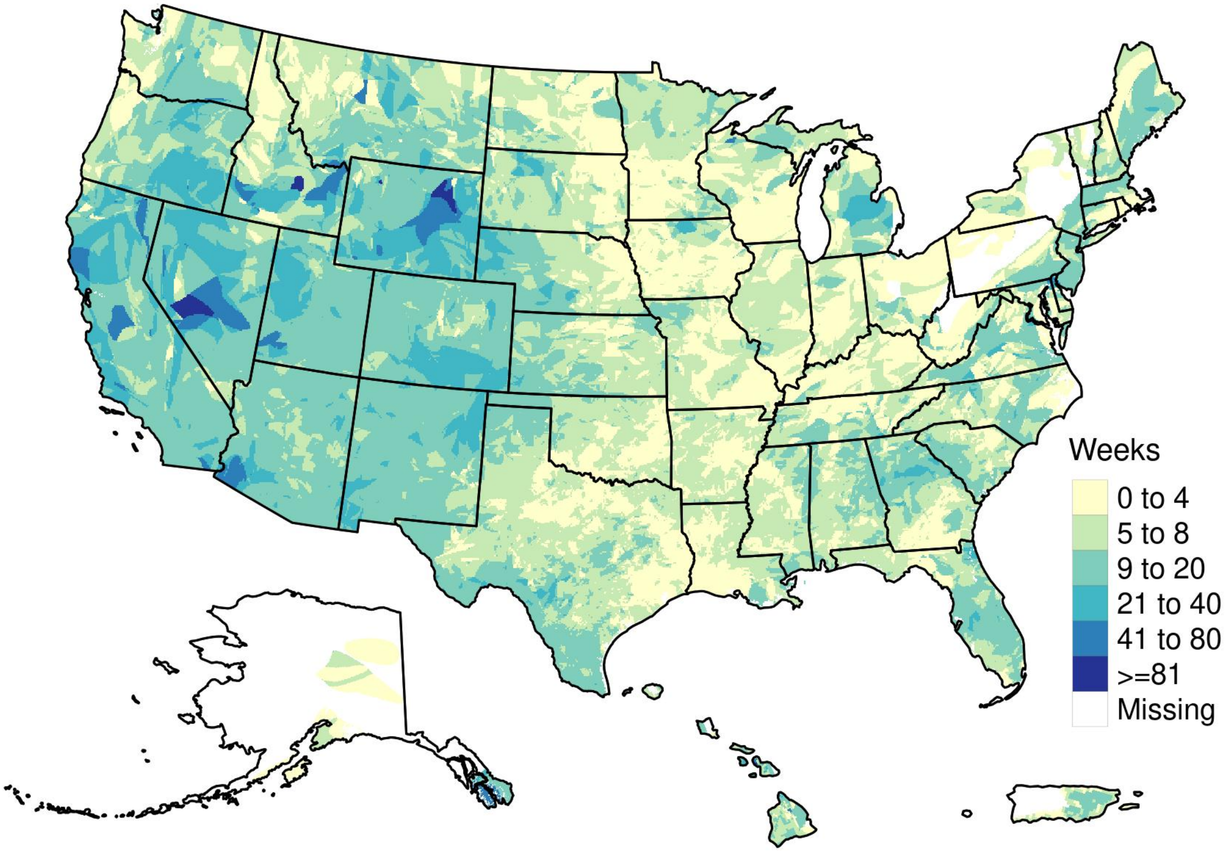

Fig. 9. The median number of weeks from drought onset to onset peak of all drought events from 2000 to 2019. This analysis excluded drought events that had peak status conditions less than D2.

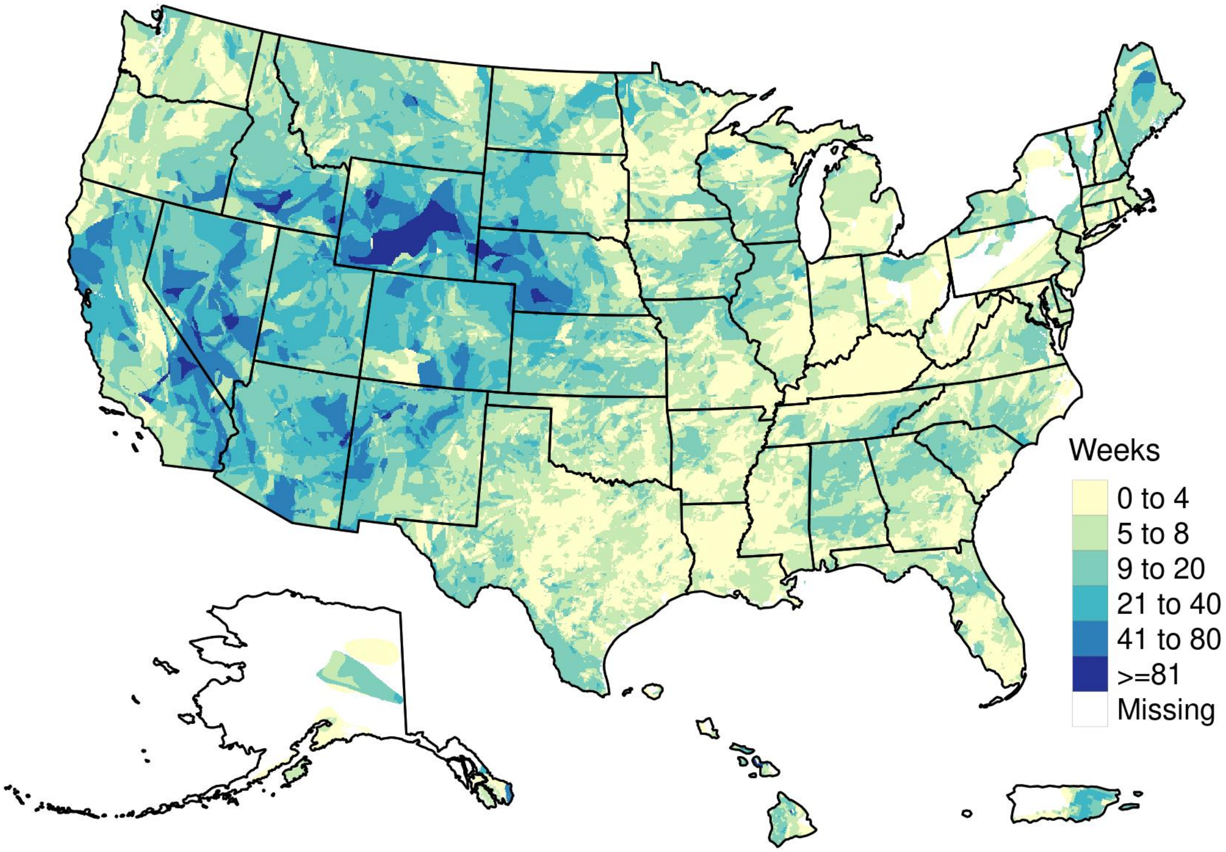

Fig. 10. The median number of weeks from peak termination to drought termination of all drought events from 2000 to 2019. This analysis excluded drought events that had peak status conditions less than D2.

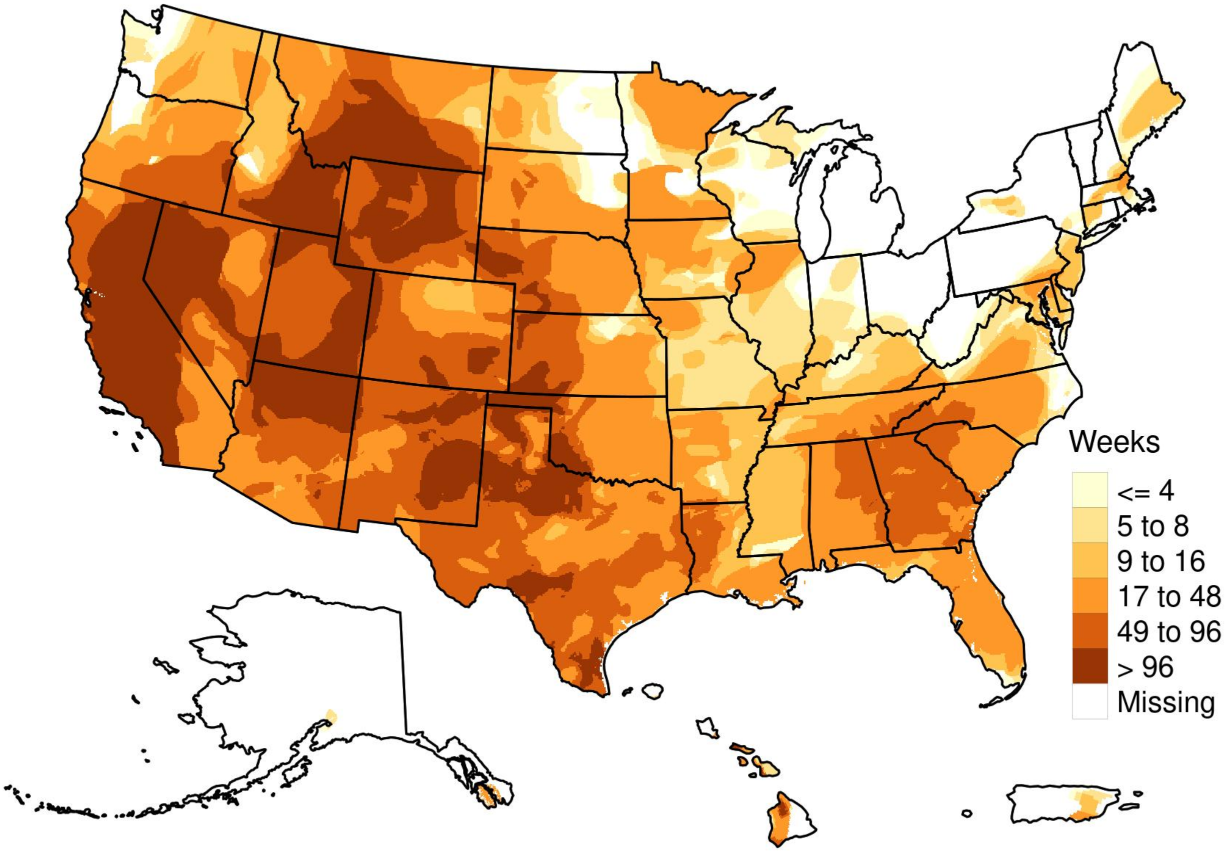

Fig. 11. Total number of drought weeks at or greater than Extreme Drought (D3) status from 2000 to 2019.

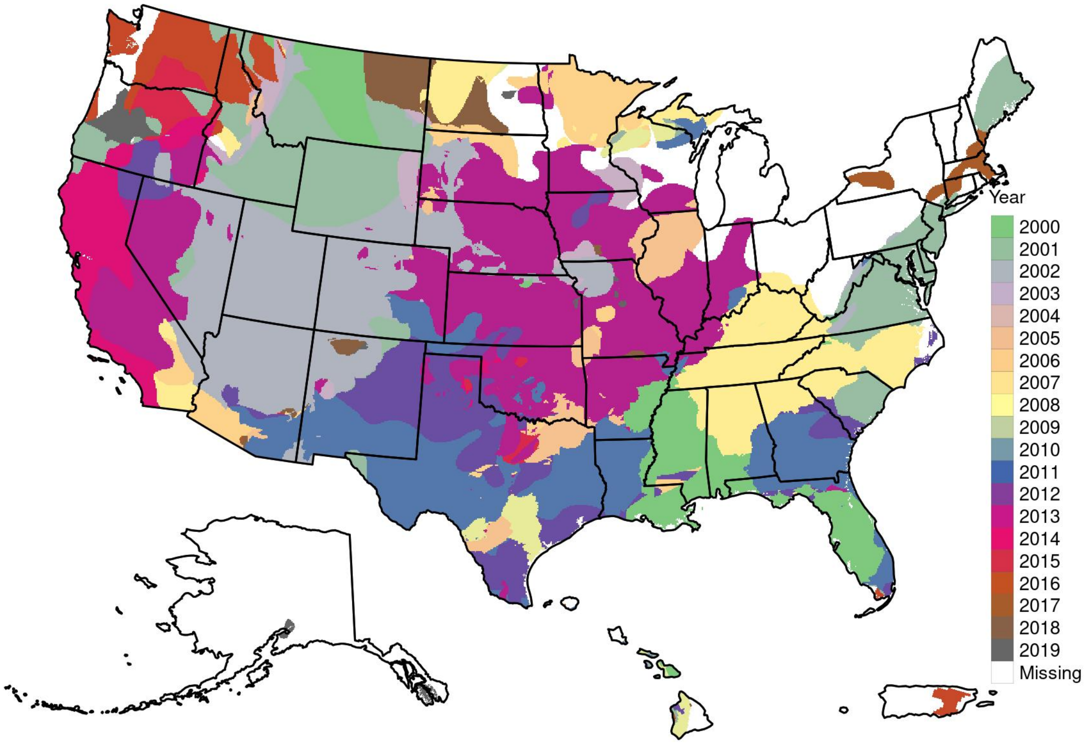

Fig. 12. Starting year of the most severe (greatest number of weeks in D3 or greater status) drought event over the USDM period of record.

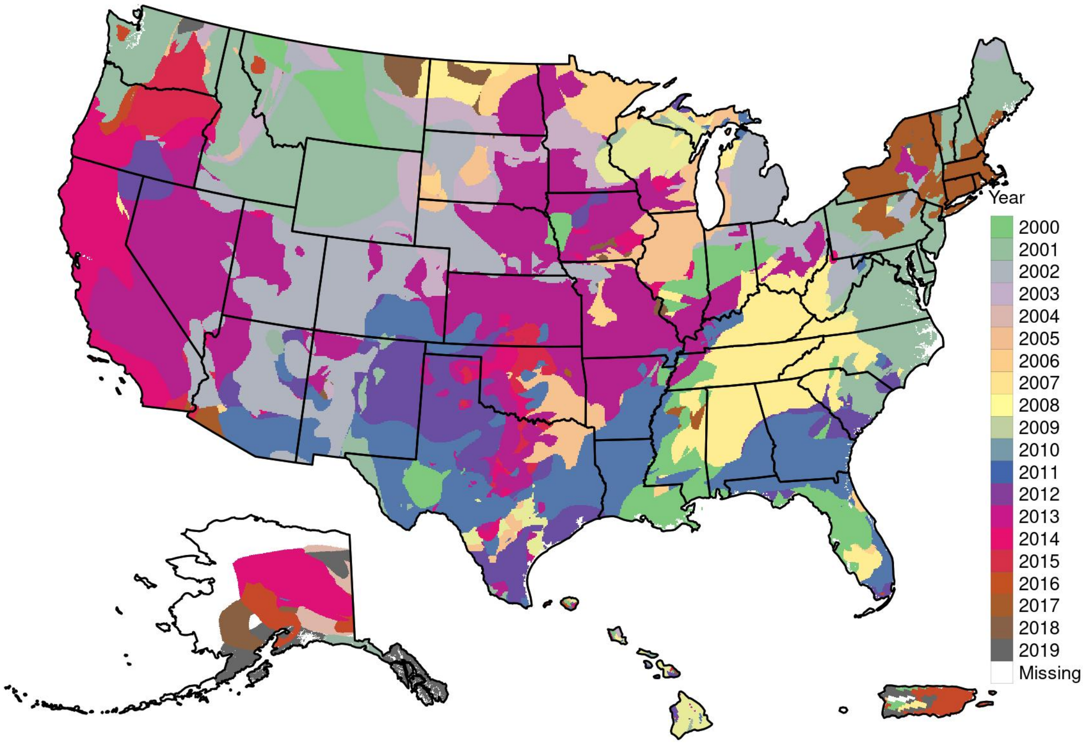

Fig. 13. Starting year of the longest-duration drought event over the USDM period of record.