

# The Role of Seasonal Precipitation Sequences in Shaping the Climate of the United States Southwest

**The climatology of the Southwest** (Arizona and New Mexico) is a result of the region's widely variable topography and geography, which influences how, when, and where seasonal moisture is distributed. The region is unique for its predominantly bimodal pattern of precipitation, with precipitation peaks in the cool season and during the monsoon. The bimodal climate is due to two different circulation dynamics, the cool season jet stream and the summer North American Monsoon, which have spatially variable impacts across the region. A consequence of these differences is a region which is far from uniform in terms of seasonal climate, but is it possible to identify subregions with similarities in pattern of precipitation seasonality? Besides the spatial

variability, how do seasonal sequences of precipitation vary over time? One sequence that is commonly recognized is the tendency for wet monsoons to follow dry winters and vice versa, but how consistent over time is this sequence? Finally, given the potential for droughts to occur in both the cool season and monsoon, how often does that occur, and is this a characteristic of recent Southwestern drought?

This study addressed these questions by examining and analyzing gridded monthly and seasonal precipitation and temperature data for the states of Arizona and New Mexico, 1896–2022.

## Goal of the Study

To develop a better understanding of the spatial and temporal variability of Southwestern seasonal climate to help anticipate climate impacts on human and natural systems, and to provide insights for resource management.

## Major Study Findings

1. There are five main sub-regions in the Southwest, characterized by different patterns of average monthly precipitation (Fig 1).

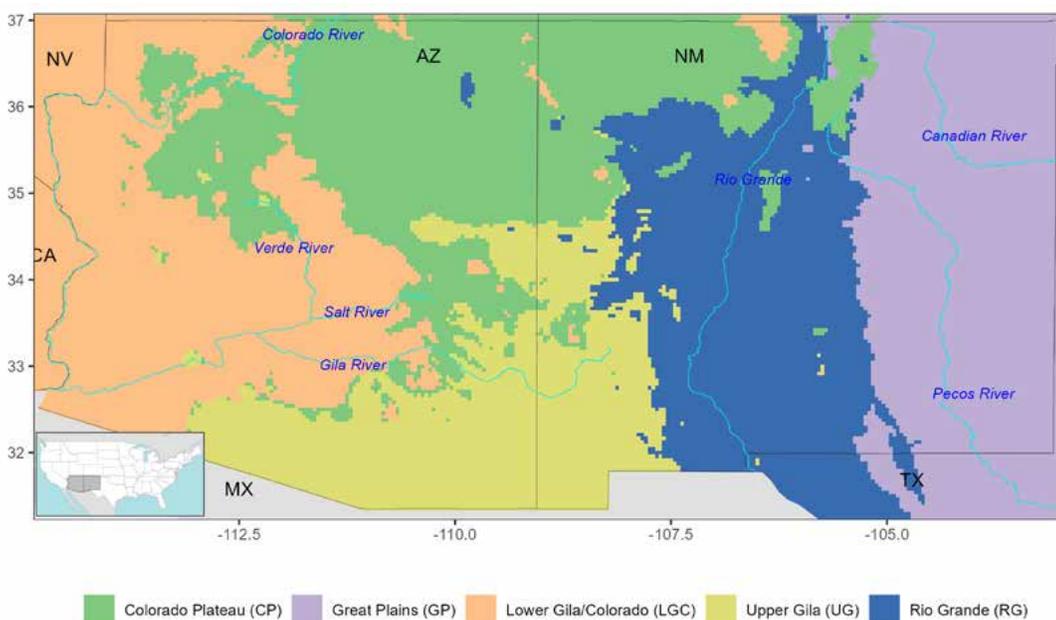


Figure 1. Five southwestern US climate regions resulting from cluster analysis of average monthly precipitation. Blue lines indicate major rivers. The inset shows the study area (Arizona and New Mexico) in the context of the US. Regions are: Colorado Plateau (CP) (green), Great Plains (GP) (purple), Lower Gila/Colorado R (LGC) (orange), Upper Gila (UG) (yellow), and Rio Grande (RG) (blue).

Of the 5 regions, all but the Great Plains region have winter and monsoon precipitation peaks, although the Rio Grande peak is small (Fig 2). Differences in the pre-monsoon (May and June) are also evident, ranging from extremely dry in the Lower Gila/Upper Colorado and Upper Gila regions, to wet in the Great Plains.

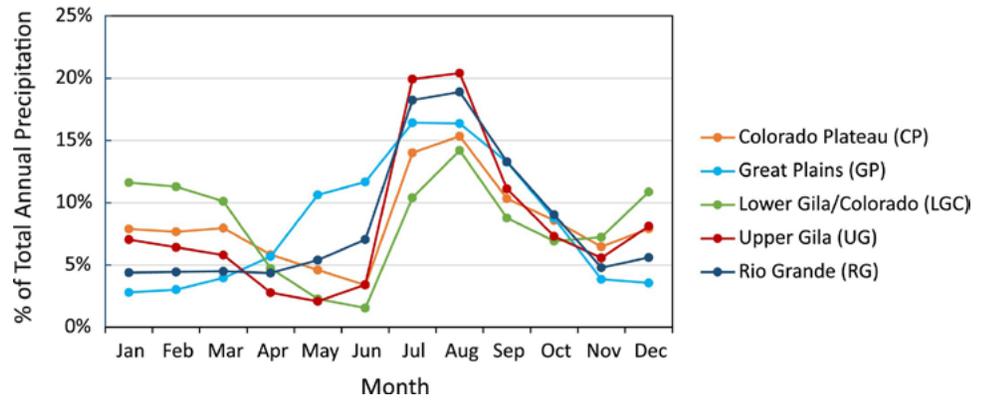


Figure 2. Percent of annual total precipitation by month, January–December, for the five subregions.

## 2. A wide variety of seasonal climate patterns across the Southwest is evident over the period of instrumental record.

While precipitation patterns are highly variable, several periods of widespread, persistent drought are evident (e.g. black boxes indicating 1950s and 2010s drought) (Fig. 3a).

Patterns of temperature clearly show the effects of anthropogenic warming, most marked since the 1990s and in summer (Fig. 3b).

Combining temperature and precipitation, the imprint of warming is also evident (Fig. 3c). While warm-dry drought conditions are particularly noteworthy, warm-wet years have also become more common in recent decades.

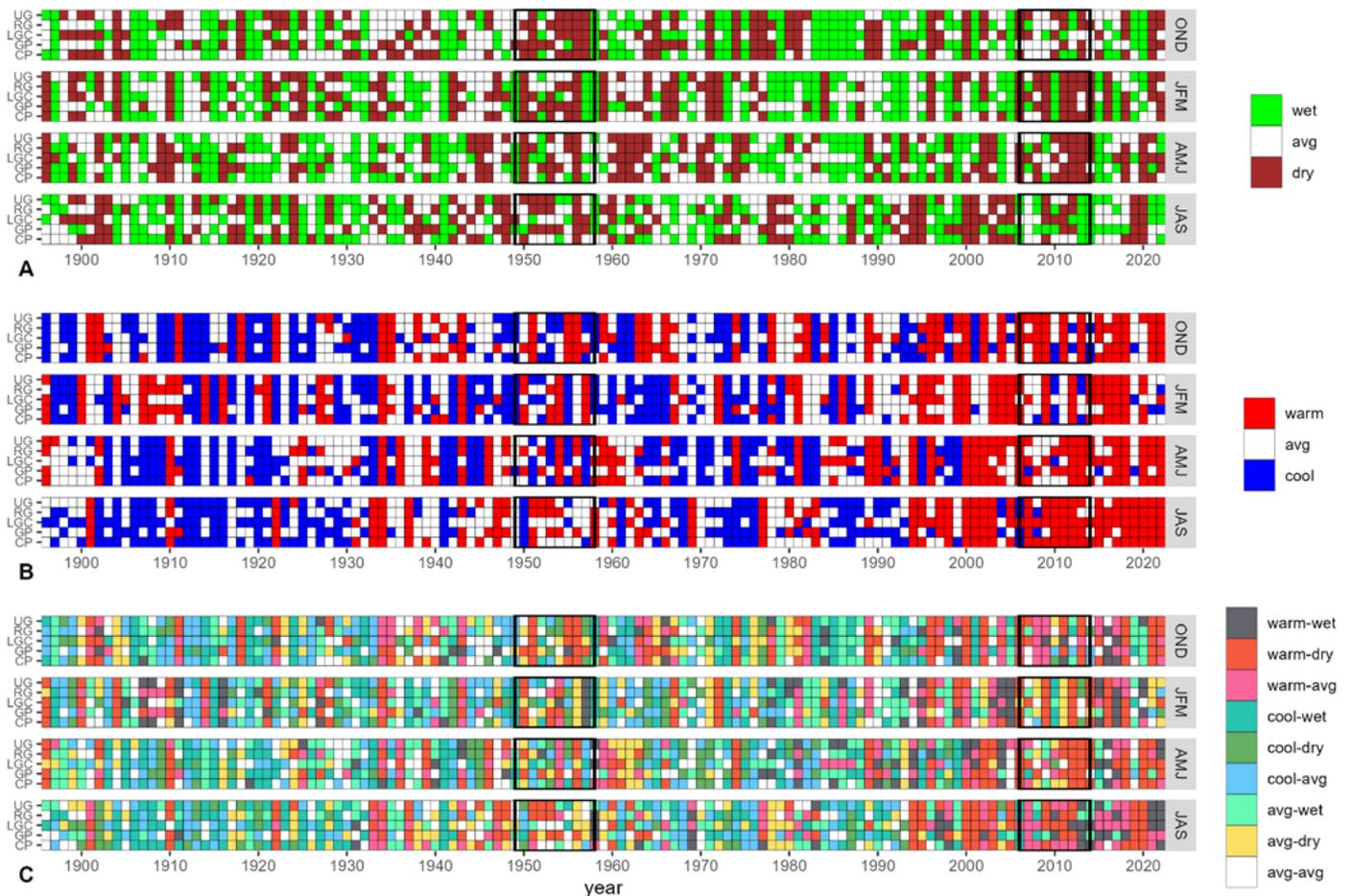


Figure 3. Variations in (A) precipitation, (B) mean temperature, and (C) climate (precipitation and temperature), 1896–2022. Each set shows seasonal conditions for each of the five subregions (rows), starting with prior fall (OND), winter (JFM), spring (AMJ), and monsoon/summer (JAS). Values have been ranked and categorized by tercile (wet, average, dry; warm, average, cool; and combinations of the precipitation and temperature categories). The years of the 1950s and 2010s droughts are outlined in black.

**3. The tendency for wet cool seasons to be followed by dry monsoons (and vice versa) (inverse season) has not been consistent over the instrumental record.**

This tendency has been most marked since about 1980 (Fig. 4c). Before the late 1930s, the tendency was for dry cool seasons to be followed by dry monsoons, and wet cool seasons to be followed by wet monsoons (dual season) (Fig 4a).

The vertical spread of the boxes in each set of plots indicates the range of numbers of years for each combination, among the 5 regions. Boxes show the most spread in the middle time period (Fig. 4b), which may have been a transition between more dual season (WW and DD) to more inverse season (WD and DW) years.

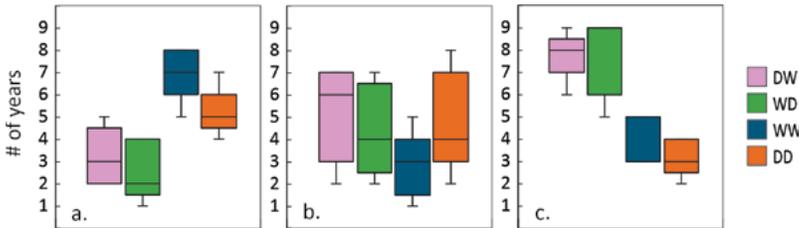


Figure 4. Box plots of numbers of years for four combinations of October–March (cool season) and July–September (monsoon season) wet and dry sequences for the five subregions (the box represents the spread among the regions), for three periods: (a) 1896–1937, (b) 1938–1979, and (c) 1980–2022. DW = dry cool season and wet monsoon; WD = wet cool season and dry monsoon; WW = both seasons wet; DD = both seasons dry. Boxes represent the 25th to 75th percentile range, the horizontal bar within the box is the median, and the extensions (“whiskers”) are within  $\pm 1.5$  times the interquartile range.

**4. A drought worst-case scenario is dry conditions in both the cool season and monsoon, but widespread dual season droughts have been rare since the 1960s.**

Persistent dual season drought years characterized the 1950s droughts, and also occurred intermittently from about 1900–1930 (Fig. 5a). Since the 1960s, widespread (more than 2 regions) dual season droughts have been rare, with the exception being the year 2000.

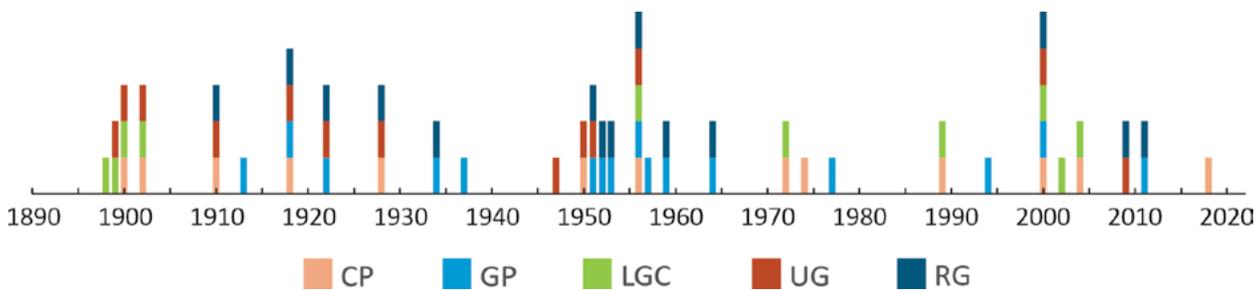


Figure 5a. Stacked bar graphs of subregions and years with dual season drought.

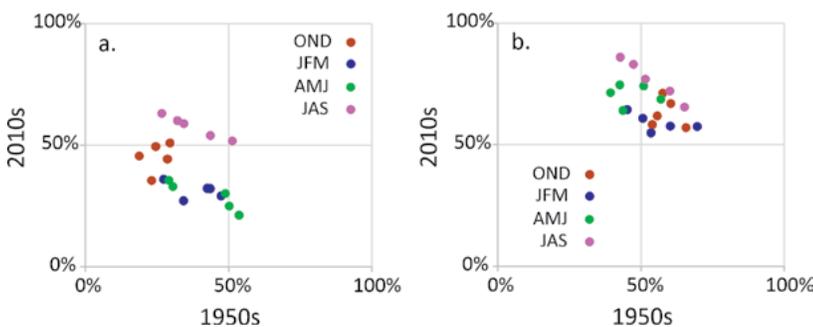


Figure 5b. Comparison of 1950s (x-axis) and 2010s (y-axis) droughts: (a) seasonal precipitation and (b) seasonal temperature. Seasons are color coded. For each season, each of the five dots represents one region’s precipitation or temperature, averaged for the years of the drought.

In contrast to the 1950s, the 2010s drought was driest in the winter and spring, while monsoon conditions were near to above median. However, the temperatures were elevated during all seasons in the 2010s drought, compared to the more moderate temperatures in the 1950s (Fig. 5b).

**For more information on this study:**

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All data sets used in this publication are from public data repositories as follows:

- (a) Gridded monthly climate data is available from <https://prism.oregonstate.edu>.
- (b) Monthly temperature and precipitation for the five climate regions: <https://doi.org/10.5281/zenodo.14727853>.

**Related blog post:** The seasonality of Southwestern US climate: does a wet monsoon follow a dry winter? [<https://climas.arizona.edu/news/seasonality-southwestern-us-climate-does-wet-monsoon-follow-dry-winter>]

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For more Information, contact:

Connie Woodhouse

Regents Professor Emerita, School of Geography, Development and Environment

University of Arizona

[Conniew1@arizona.edu](mailto:Conniew1@arizona.edu)

