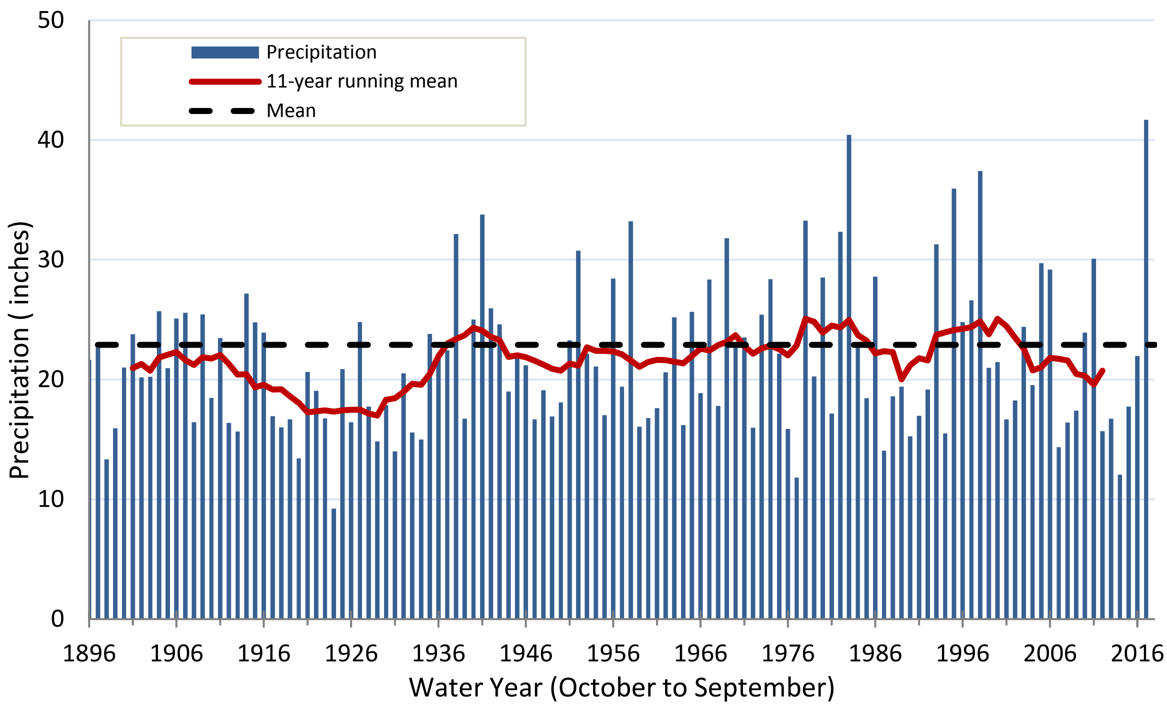
PRECIPITATION

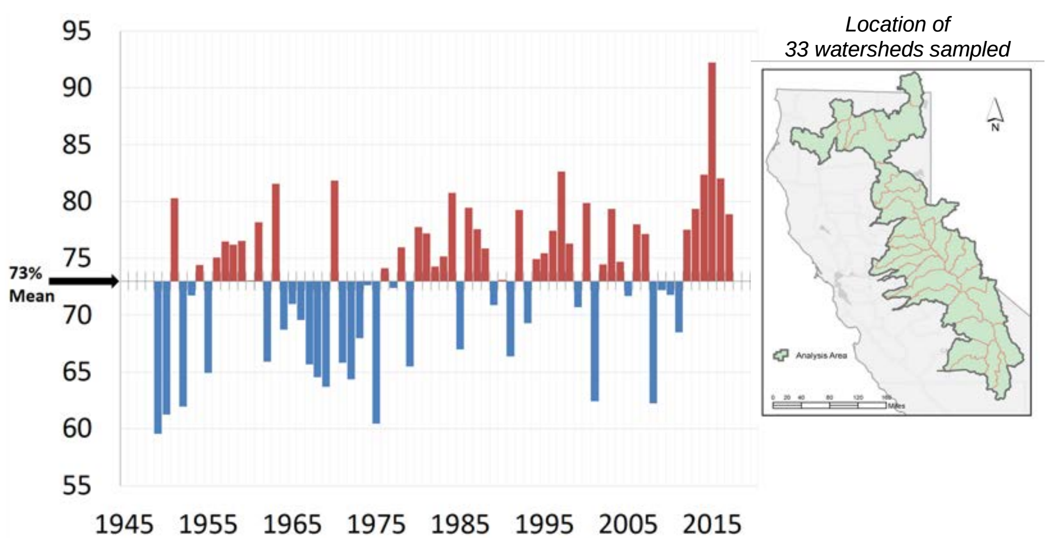
The total amount of precipitation varies greatly from year to year and statewide shows no apparent trend, however year to year variability has increased since 1980. In recent years, the fraction of precipitation that falls as rain over the watersheds that provide most of California's water supply has been increasing.

Figure 1. Statewide annual precipitation



Source: WRCC, 2017

Figure 2. Rain as percentage of total precipitation (1949-2017)



Red bars show years with a higher percentage of rain than the mean; blue bars have a lower percentage of rain than the mean.

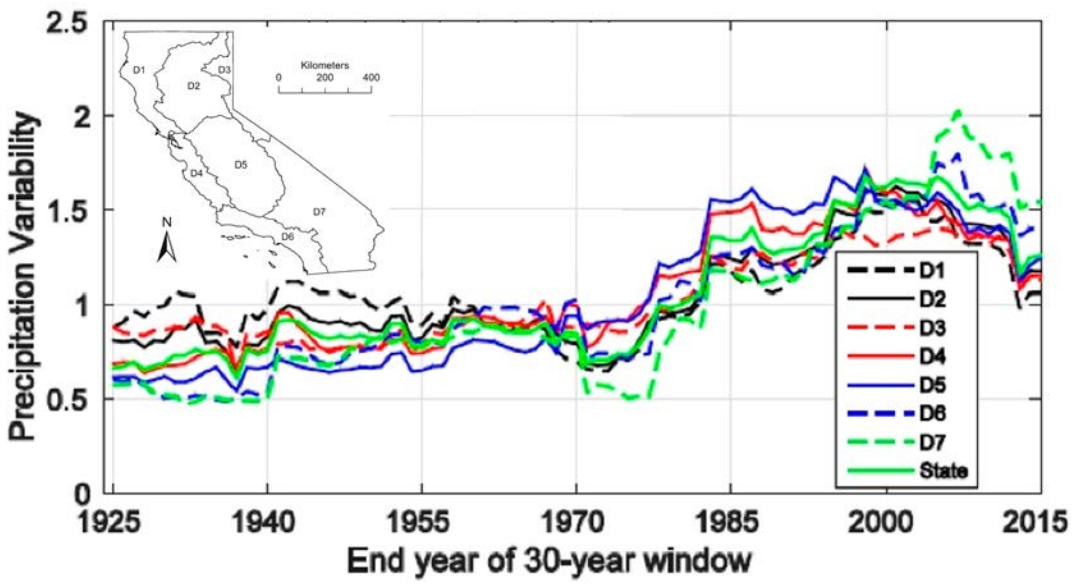
Source: DWR, 2017

What does the indicator show?

No clear trend is evident in the amount of annual precipitation. Statewide precipitation has been variable from year to year, with a consecutive dry then wet year occurring many times since 1895. Statewide precipitation is the area-weighted average of regional precipitation values. (In other words, the regional precipitation values — computed as an area-weighted average of precipitation at the climate stations in the region — are weighted by the area covered by each region, and an average calculated as the statewide value).

Variability in annual precipitation statewide and across the regions of the state has increased since the early 1980s, peaking in the late 1990s for most climate divisions (Figure 3) (He & Guatam, 2016). This shows that dry and wet precipitation extremes have become more frequent.

Figure 3. Statewide and regional annual precipitation variability*



Source: He and Guatam, 2016

* *30-year moving window of annual precipitation variability statewide, and for NOAA climate divisions (see map, inset). For each year, the value shown is the ratio of the variance for the 30-year period ending in that year to the variance over the entire period. A ratio above 1 means precipitation was more variable; below one, less variable.*

Since records began in 1895, statewide annual precipitation has ranged from a low of 9.4 inches in 1924 to a high of 41.66 inches in 2017. Precipitation in seven of the last ten years has been below the statewide average of 22.9 inches (the dashed line in Figure 1). The water years of 2012 to 2015 set a record for the driest consecutive four-year period of statewide precipitation.

With regard to physical state, precipitation lands on the surface as rain or snow depending on the temperature of the air and the ground, the local geography, and the characteristics of the storm itself. Figure 2 shows the percentage of yearly precipitation falling as rain over the 33 watersheds that provide most of the state's water supply (see inset map). Each value shown represents the difference between that year's percentage of rain compared to the average for the entire period (1949 to 2016), which is 73 percent. Red bars show years with more rain than average (and thus less snow), and blue bars show years with less rain than average. While there is high year-to-year variability, recent years clearly show a trend toward more precipitation falling as rain. The 2015 water year, which had the lowest snowpack on record, also had the highest percentage of rain, at about 92 percent.

Why is this indicator important?

Precipitation, in the form of rain and snow, is the primary source of California's water supply. On average, 75 percent of the state's annual precipitation occurs from November through March, with 50 percent occurring from December through February. Precipitation totals are tracked by "water year," from the beginning of the rainy season in October through the following September, the end of the dry season.

Under climate change, more intense dry periods under warmer conditions are anticipated, leading to extended, more frequent drought in California. A higher proportion of precipitation falling as rain instead of snow and an increase in the duration, frequency, and intensity of warm, wet "atmospheric river" storms are also projected (see *What factors influence this indicator?*). In recent years, greater attention on atmospheric rivers has revealed their role in ending persistent droughts (Dettinger, 2013) and in producing large floods (Dettinger, 2011).

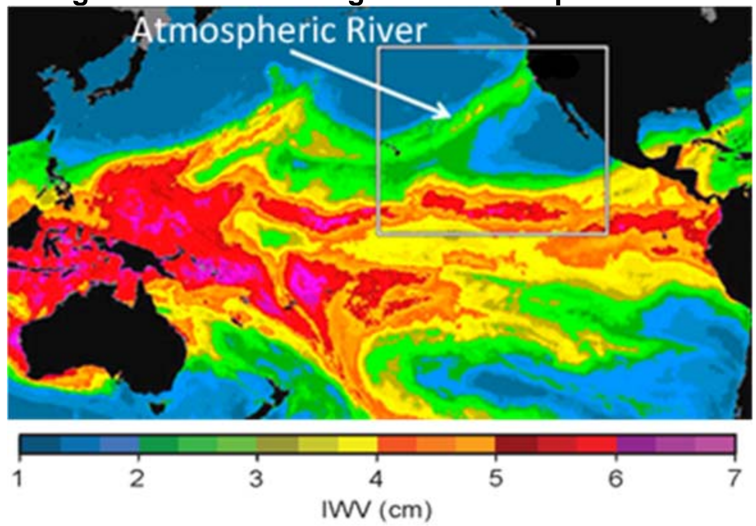
Tracking trends in the amount and physical state of precipitation, and in the patterns of storm events, is critical to water management in California. During warmer months, the state relies on snowpack melting from the Sierras to meet its water demand. The fraction of precipitation falling as rain significantly affects how much water is stored in snowpack. Information on trends plays an important role in balancing the multiple water management objectives of reservoir operations, including storage and flood protection. Historical trends help inform short-term water management planning, and provide the basis for future projections.

What factors influence this indicator?

Global scale weather patterns bring moisture to California, primarily from the Pacific Ocean. Most of the water vapor that provides the state's precipitation comes from the Pacific Ocean. The variability in the state's precipitation is related to El Niño and La Niña in the tropical Pacific, and to conditions in the northern Pacific and near Indonesia. Ocean conditions change slowly, over periods of months to years to decades, with similarly prolonged effects on adjacent land.

Atmospheric rivers, mentioned above, represent an important feature of California's precipitation. These storms provide 30 to 50 percent of California's annual precipitation, and 40 percent of the Sierra Nevada snowpack. Atmospheric rivers are long, narrow bands of water vapor, greater than 1,000 miles long and typically about 250 to 370 miles wide, that originate over the Pacific Ocean (see Figure 4; colors represent the amount of water vapor, or IWV). A natural part of the global water cycle, these constantly moving atmospheric rivers are responsible for most of the horizontal transport of water vapor outside of the tropics (NOAA, 2017).

Figure 4. Satellite image of an atmospheric river



Source: NOAA, 2017

In California's Mediterranean climate, summers are typically dry. In the southeastern desert regions, including the Sonora and Mojave deserts, some monsoonal activity in the summertime may bring thunderstorm precipitation. Summers are characterized by a blocking high pressure zone that diverts atmospheric moisture away from the state. Precipitation deficits during the recent drought have been associated with a prominent region of high pressure nicknamed the "ridiculously resilient ridge" that diverted storm tracks northward during California's rainy season in 2012 to 2015 (Swain, 2015).

Local terrain influences precipitation. For example, as the atmosphere is pushed up the slope of a mountain range, the water vapor cools and condenses if the air is moist enough. This often forms clouds on the upslope and over the mountain crest, and can cause precipitation to fall. This phenomenon is called orographic forcing.

Average annual precipitation varies greatly among California's eleven climate regions, as defined by the Western Regional Climate Center: from 4.4 inches in the Sonora Desert to 64.4 inches in the North Coast. As with statewide precipitation, annual variability has increased across most regions, peaking in the late 1990s, except in Southern California (which includes the South Coast, South Interior, Mojave Desert and Sonoran Desert regions) where it peaked in 2007 (He and Guatam, 2016). Regional graphs are shown in the appendix.

In the Sierra Nevada, the last 35 years have brought some of the wettest and driest winters, including several multi-year wet and dry periods. Dry years since and including 1976-77 have approached the driest single year ever recorded in 1924; two of the past ten years, 2014 and 2015 were among the ten driest years (third and eighth, respectively). Snowpack in the Sierra Nevada provides natural water storage for California, therefore precipitation in this area has major statewide impacts and draws intense interest.

Technical Considerations

Data Characteristics

Data are from the California Climate Tracker, an operational database tracker for weather and climate monitoring information. This indicator tracks precipitation amount in a "water year" defined as October 1 to September 30. This is more useful than a calendar year in California due to the typically dry summer and wet winter ("Mediterranean") climate. This operational product, the California Climate Tracker, is updated monthly online at the Western Regional Climate Center http://www.wrcc.dri.edu/monitor/cal-mon/index.html. Software and analyses were produced by Dr. John Abatzoglou (Abatzoglou et al., 2009).

Precipitation data for nearly 200 climate stations in the NOAA Cooperative Network (COOP) within California were obtained from the Western Regional Climate Center database archive of quality controlled data from National Climatic Data Center. For this study, COOP data from 1948-2007 were utilized. Gridded climate data from Parameter-elevation Regressions on Independent Slopes Model (Daly et al., 1997) was acquired from the PRISM group at Oregon State University for the period 1895-2007. PRISM provides complete spatial coverage of the state, where the station data serve to fill in recent data, until PRISM is processed each month. Because climate stations are not evenly spaced, the PRISM data are used to provide even and complete coverage across the state. These are combined to create a time series of annual statewide precipitation dating back to 1895.

Strengths and Limitations of the Data

The datasets used in this work were subjected to their own separate quality control procedures, to account for potentially incorrect data reported by the observer, missing data, and to remove inconsistencies such as station relocation or instrument change. The PRISM data offers complete coverage across the state for every month of the record. Limitations include the bias of station data toward populated areas, and limited ability of quality control processes in remote or high terrain areas. The results cited here offer a hybrid using both gridded and station data, which is suggested to be more robust than either data set used independently (Abatzoglou et al., 2009).

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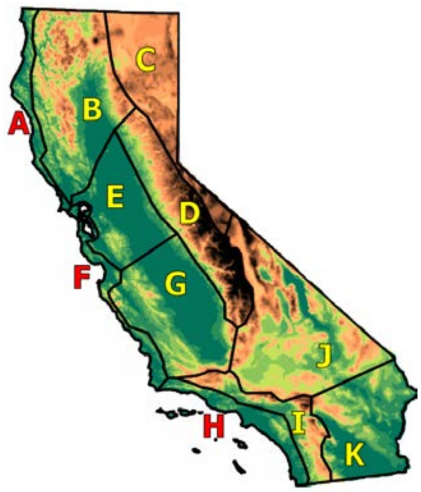
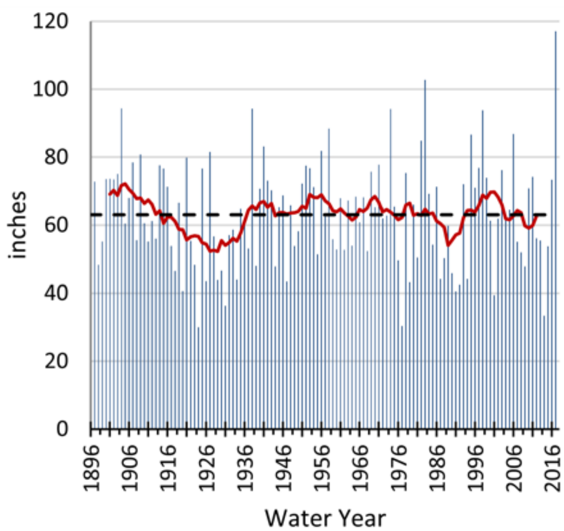
APPENDIX. Regional precipitation trends in California's climate regions (as defined by the Western Regional Climate Center)



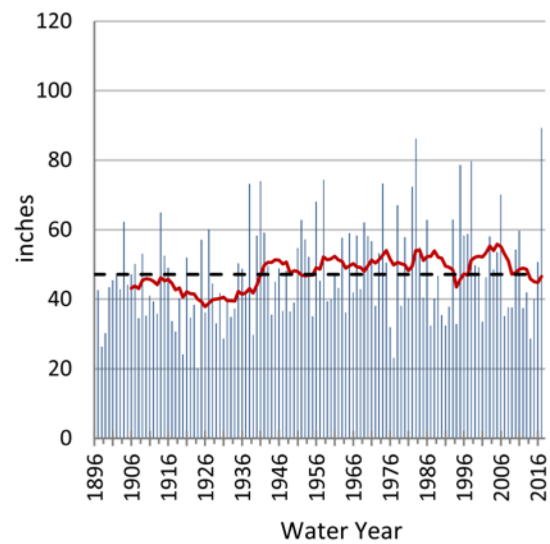
Region	Average precipitation (inches)
A. North Coast	64.4
B. North Central	51.0
C. Northeast	23.8
D. Sierra	39.2
E. Sacramento-Delta	19.7
F. Central Coast	25.2
G. San Joaquin Valley	12.5
H. South Coast	17.4
I. South Interior	17.8
J. Mojave Desert	7.3
K. Sonoran Desert	4.4
Statewide	22.9

Source: WRCC, 2017

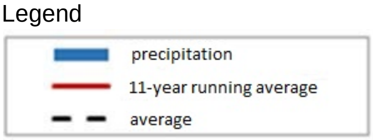
North Coast Region



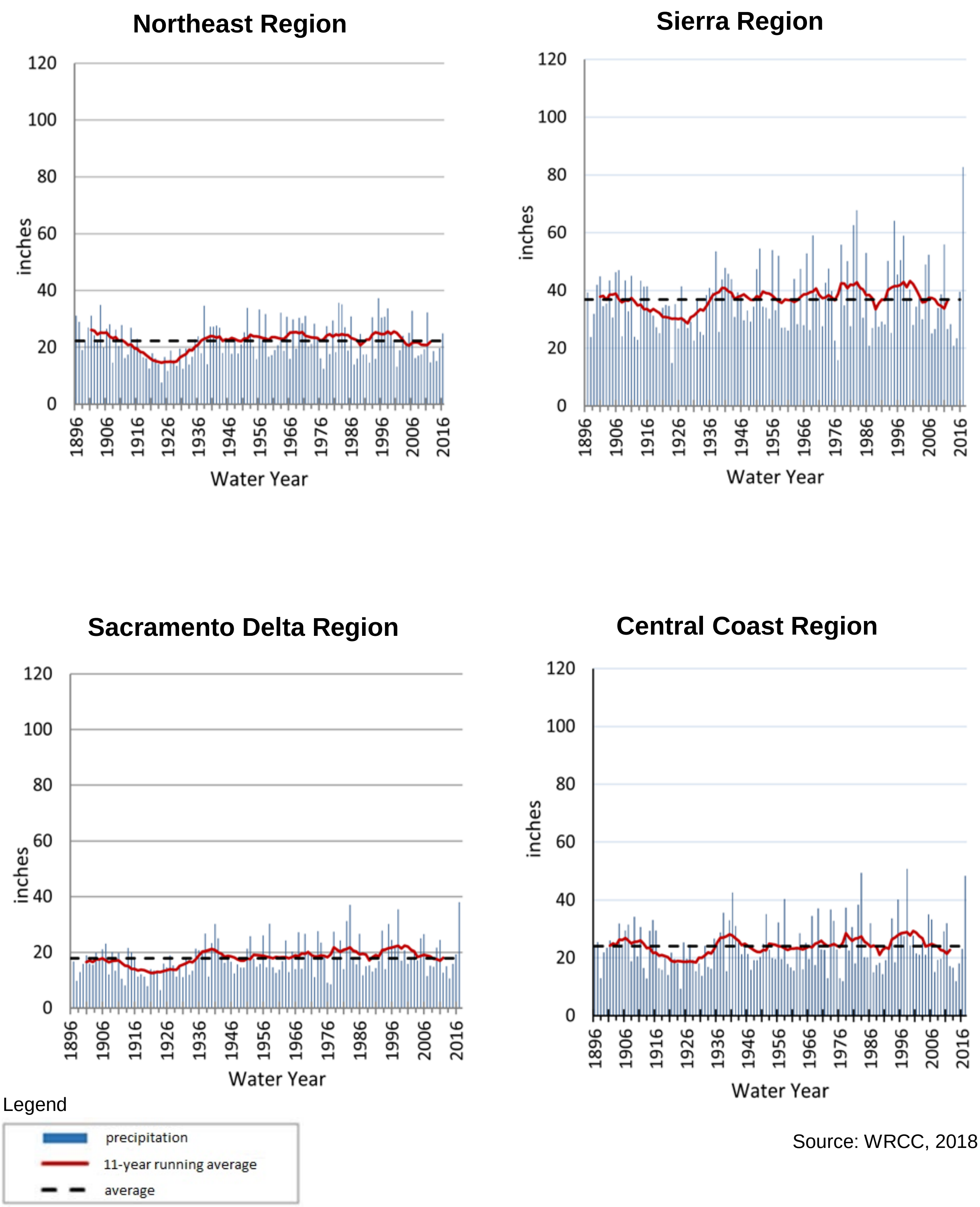
North Central Region



Legend

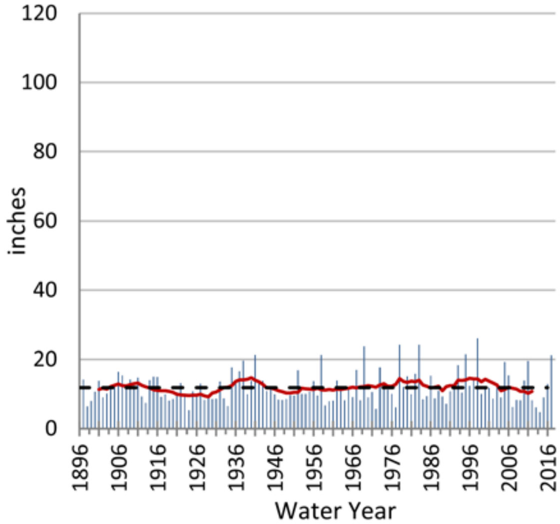


Source: WRCC, 2018

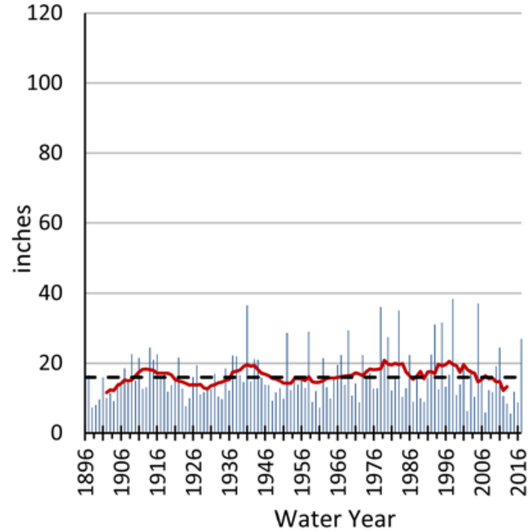


Source: WRCC, 2018

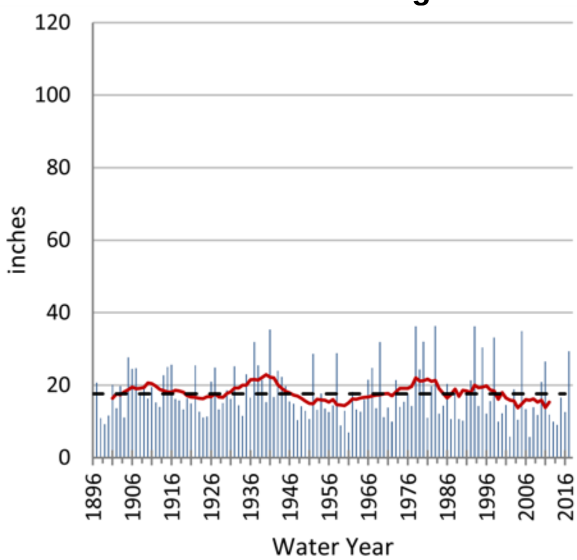
San Joaquin Region



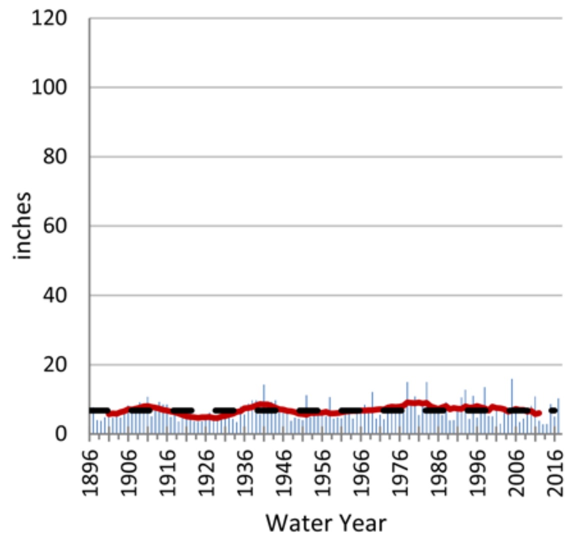
South Coast Region



South Interior Region



Mojave Region



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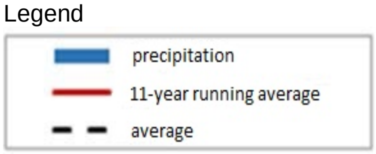
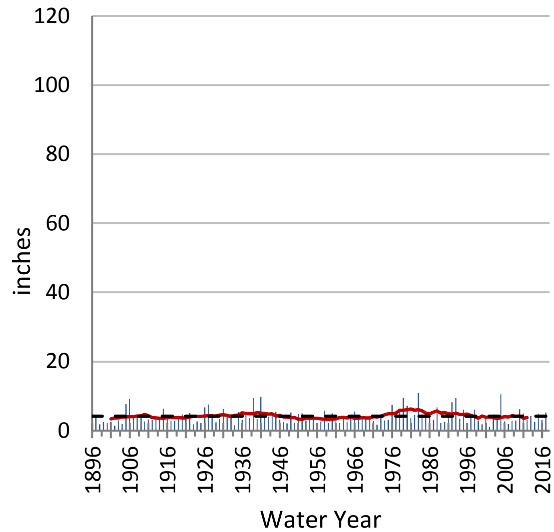


Source: WRCC, 2018

Sonoran Desert Region



Source: WRCC, 2018

Legend