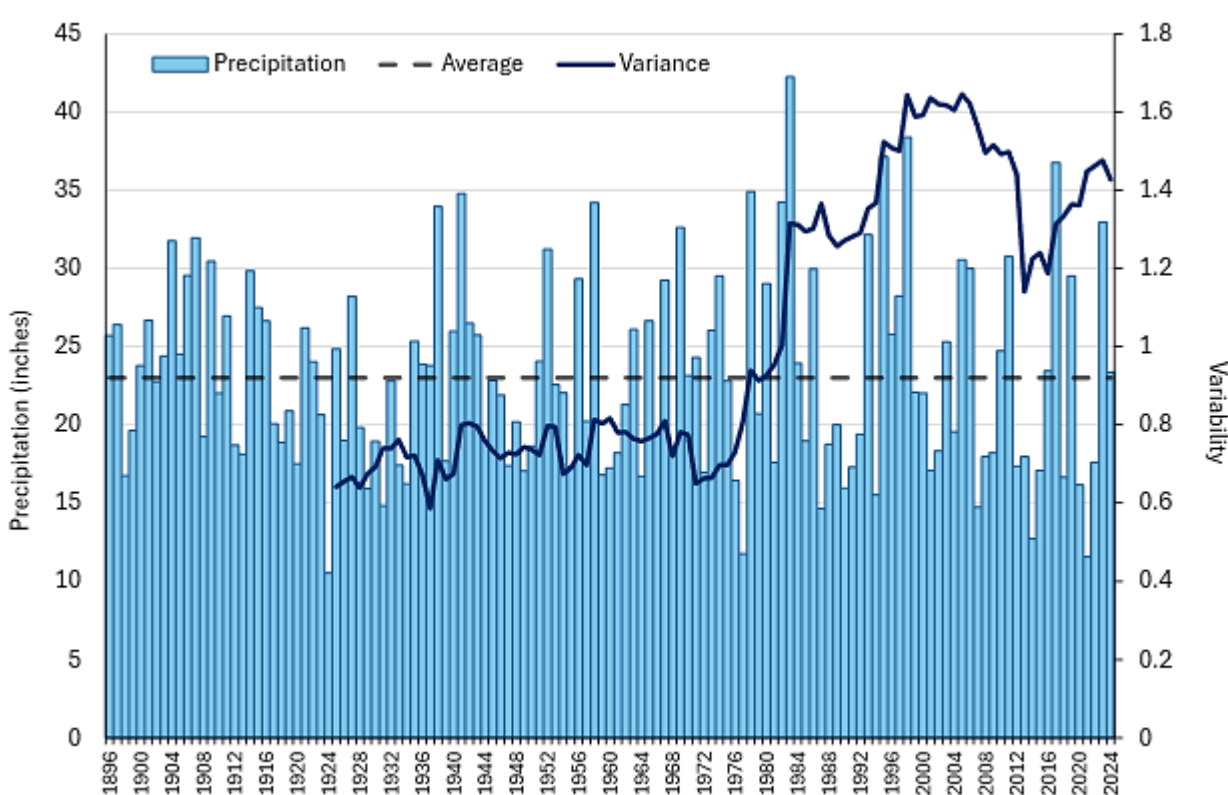


2.2 Precipitation

Although total annual precipitation does not show a consistent statewide trend, California's year-to-year variability has increased since the 1980s. In recent years, the fraction of precipitation that falls as rain instead of snow has increased in the Sierra Nevada and Southern Cascades, reducing the water stored in the snowpack that provides most of California's water supply.

Figure 2.2.1. Statewide Total Annual Precipitation (1895–2024).



Blue bars show total statewide precipitation by water year (October–September). The dotted grey line is the long-term average of annual totals (23.02 inches). The dark blue line shows variability: each value (from 1925) is the annual ratio of 30-year variance to total variance (1895–2024), as a measure of how variable each year is relative to long-term historical patterns. Values above 1 indicate more variability; below 1, less. Source: WRCC (2025)



What does the indicator show?

California's total annual precipitation is characterized by high year-to-year variability (**Figure 2.2.1**, also see Dettinger, 2011). Since records began in 1895, statewide annual precipitation has ranged from a low of 10.52 inches in 1924 to a high of 42.26 inches in 1983. No clear trend is evident in the amount of total annual precipitation (**Figure 2.2.1**, blue bars).

Tribal Connection 2.2.1

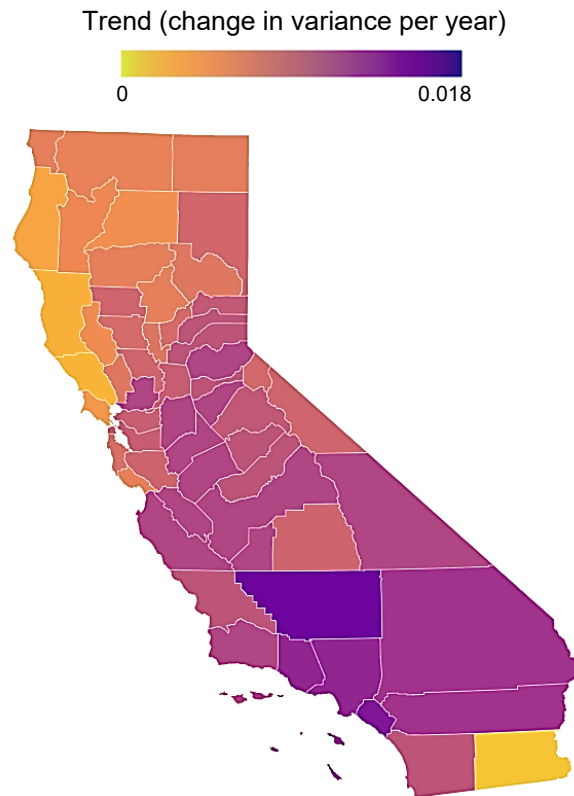
Some areas have seen a reduction in precipitation: the Pala Band of Mission Indians in San Diego County are receiving less annual rainfall over time, since 1895. However, *"When the rains come, these rain events are becoming more intense, causing flooding that rises and falls quickly (Prosper Sustainably, 2018). The Pala Environmental Department tracks rainfall, water flows, stream levels, storm damage, and flooding at multiple locations on the Reservation. Flooding has become a regular occurrence at Pala. Between 1917 and 1997 there were two major flood events. Since 1997 there have been 23 major floods that covered roads, damaged property, and trapped residents"* (Pala Band of Mission Indians, 2026).

Since the early 1980s, year-to-year precipitation has become increasingly variable (**Figure 2.2.1**, solid dark blue line), with notable regional differences (**Figure 2.2.2**) across the state (note: **Figure 2.2.2** shows long-term trends in variability, i.e. the estimated change in variance each year, whereas **Figure 2.2.1** shows annual values). This increasing variability—often referred to as hydroclimatic "whiplash"—reflects more frequent and abrupt shifts between extremely wet and dry years.

Recent decades illustrate this pattern. The past decade included both the fourth wettest year on record (2017) and the second driest (2021). The period from 2012 to 2015 set a record for the driest consecutive four-year historical record, followed shortly after one of the wettest three-year periods (2017 to 2019). Similarly, 2020 to 2022 were the driest consecutive three-year period of statewide precipitation, followed by a wet year for 2023.



Figure 2.2.2. Interannual Precipitation Whiplash by County.

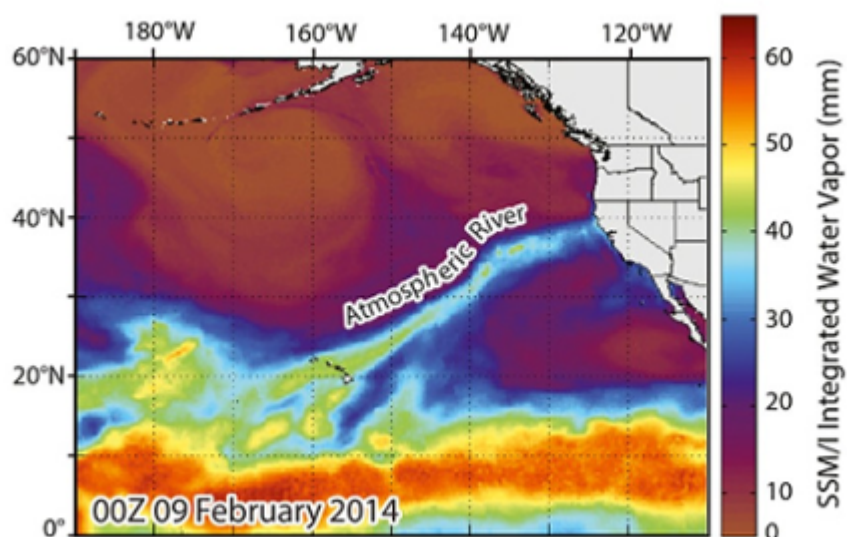


The map shows trends in interannual variability, as measured by the ratio of 30-year variance to total variance (1895–2024) for each county. Trends are the slopes of the trendlines, where higher values indicate greater rates of change. Statewide, variance is increasing at an average rate of 0.01 each year. Source: WRCC (2025)

Approximately 30 to 50% of California’s annual precipitation and about 40% of the Sierra Nevada snowpack comes from long, narrow bands of water vapor (greater than 1,000 miles long and typically about 250 to 370 miles wide), known as atmospheric rivers ([Figure 2.2.3](#); Dettinger, 2013; Guan et al., 2010). A natural part of the global water cycle, they transport most of the water vapor outside of the tropics. Some atmospheric rivers originate from the Pacific Ocean near Hawaii and make landfall in California, where they can release water vapor in the form of heavy rain or snow (NASA, 2021; NOAA, 2025).



Figure 2.2.3. Satellite-Derived Image of an Atmospheric River.

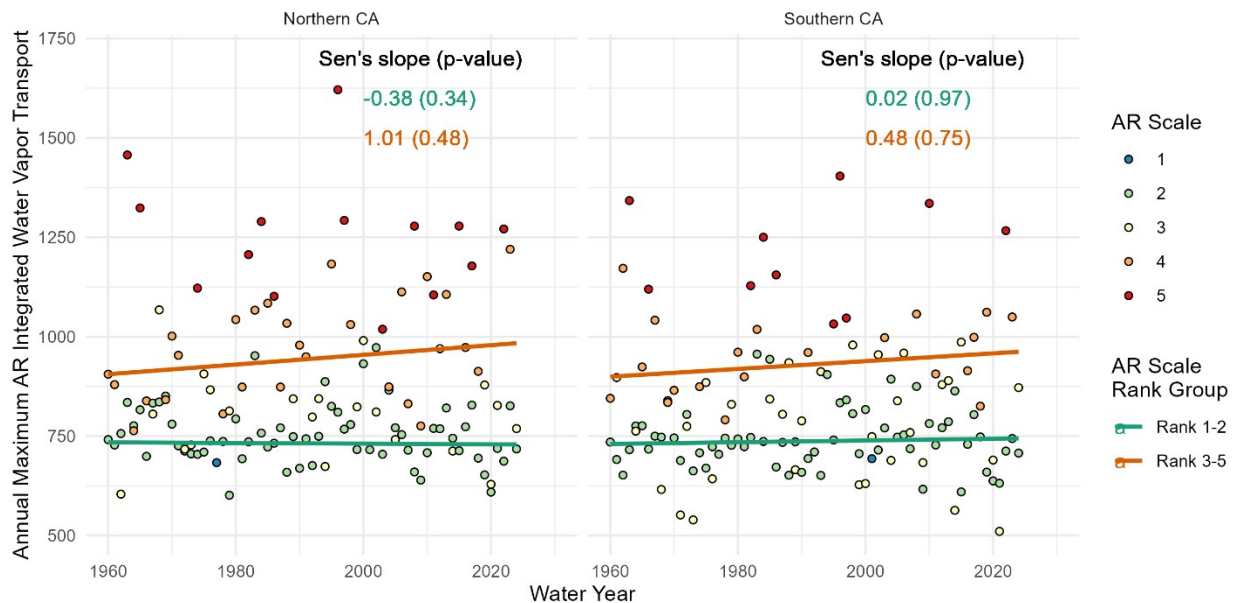


Satellite-derived image showing an atmospheric river along the western United States, depicted as a long, narrow band of high integrated water vapor (colors represent atmospheric moisture content). Source: Hatchett et al. (2017a)

Atmospheric rivers are categorized by intensity and duration (ranked on a scale of 1 to 5, with 1 being the least amount of water vapor and shortest duration). The intensity of these events along the California coast is expected to increase as the climate warms and the atmosphere can hold more water (Payne et al., 2020), and precipitation extremes are expected to be driven by the largest events (Gershunov et al., 2019; Warner et al., 2014). Since the 1960s, the strongest atmospheric rivers (Categories 3 to 5) have increased in frequency, large interannual variability, thus no significant change has yet been detected (Gershunov et al., 2025 and [Figure 2.2.4](#)).



Figure 2.2.4. Atmospheric Rivers in California.

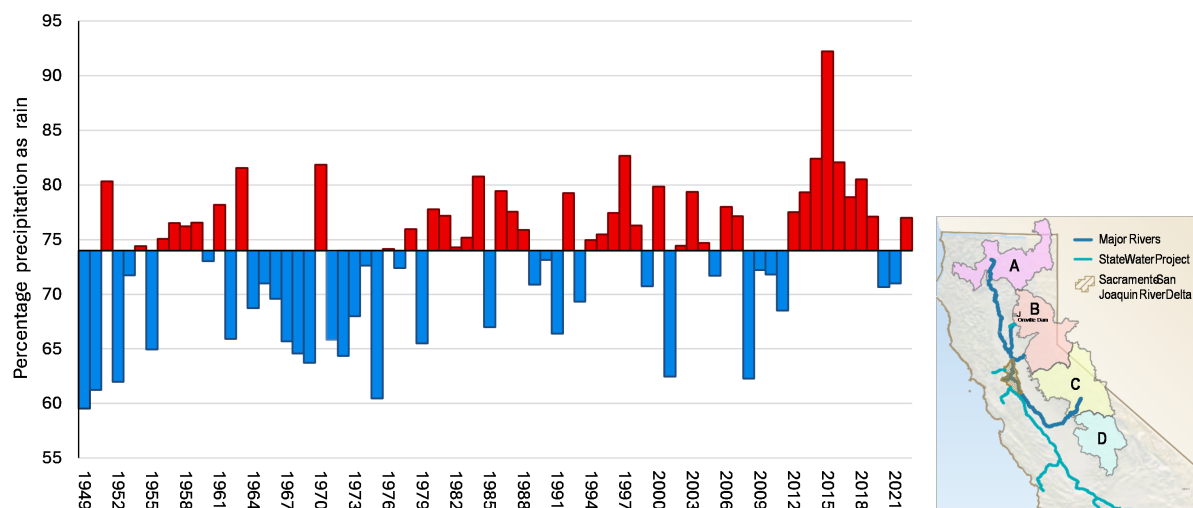


Annual maximum integrated water vapor transport (IVT) in Northern and Southern California for weak (Rank 1–2) and strong (Rank 3–5) groupings of atmospheric rivers. Points show yearly values and are colored according to the rank of the largest AR in the group and lines show trends for weak and strong, which are small and not statistically significant. Source: Center for Western Weather and Water Extremes, Scripps Institution of Oceanography (2025)

Figure 2.2.5 shows the percentage of yearly precipitation falling as rain over the 33 watersheds that provide most of the state's water supply. Values represent whether each year has precipitation falling as rain than the historical average. Each value is calculated as the difference between that year's percentage of rain compared to the long-term average (74%, black line) for the entire period (1949 to 2022). Red bars show years with more rain than average (and thus less snow), and blue bars show years with less rain than average. Despite high year-to-year variability, recent years clearly show a trend toward more precipitation falling as rain. The percentage of precipitation falling as rain for eight of the last 10 years was higher than average. The 2015 water year, which had the lowest snowpack on record, also had the highest percentage of rain, at about 92%.



Figure 2.2.5. Rain as a Percentage of Total Precipitation (1949–2022).



Annual percentage of precipitation falls as rain in major California water-supply watersheds. Red bars indicate years above the long-term mean (74%), and blue bars indicate years below the mean. The map shows the watershed zones included in the analysis. Source: DWR (2024)

Why is this indicator important?

Precipitation, in the form of rain and snow, provides most of California's supply of water. The fraction of precipitation falling as rain significantly affects how much water is stored as snow. During warmer months, the state relies on Sierra Nevada snowmelt to meet a large fraction of its water demand. Tracking changes in the amount and physical state of precipitation, and in the patterns of storm events gives critical information for balancing the multiple water management objectives of reservoir operations, including storage and flood protection.

Historical trends help inform short- and long-term water management planning and provide the basis for future projections (Siirila-Woodburn et al., 2021; Sterle et al., 2019). The availability of water has significant implications for California's people, environment, and economy (see the *Drought* and *Coastal Flooding* chapters). People who are historically marginalized, often low-income and people of color, are disproportionately impacted by lack of water (in the form of droughts) or extreme



precipitation (such as with floods) and have limited ability to prepare for or adapt to such events that will become increasingly common with climate change.

Changes in the timing of precipitation are also important to track. A comparison of historical and current precipitation (1960–1989 vs 1990–2019) averaged across the state shows a change in the monthly distribution of precipitation (Luković et al., 2021). This study found a later onset of the rainy season, with less precipitation early in the wet season, and greater concentration of precipitation during the winter months, resulting in a shorter, more intense rainy season in California. These observed changes are consistent with climate change projections (Oakley et al., 2019; Polade et al., 2014; Swain et al., 2018).

Tribal Connection 2.2.2

Variable precipitation, larger atmospheric rivers, and increased flooding in low-lying areas are impacting the lifeways of the Wiyot Tribe around Humboldt Bay or Wigi. *“Wiyot basketweavers and berry pickers must gather plant material and fruit at particular times of year. Gathering camps have traditionally been established around August and September when plants are in the best condition for harvest and traditional uses. [...]. Early precipitation can cause less or incomplete ripening of berries, a process which is dependent on there being sunnier days in the period before the cold season arrives. Losses of material and food due to weather are compounded by the fact that the majority of the Wiyot’s historically and culturally important gathering sites were incorporated into National and State Parks. Tribal members are no longer permitted to gather in those areas and may face consequences for trying to access ancestral gathering grounds. This makes it even more important that the sites that Tribal members can still access are productive”* (Wiyot Tribe, 2026).

Along with providing water to people in California, precipitation also nourishes the natural environment. Changes to precipitation or water availability can manifest in ecosystems in various ways. The record droughts of 2012–2016 and 2020–2022 contributed to significant tree mortality, wildfires, fish die-offs, and harmful algal blooms, while also straining water systems (Sum, 2024; Hartman et al., 2025).



Sharp shifts from extremely dry to extremely wet years can have major impacts. For example, California's recent rapid shift from severe drought (2012–2016) to heavy precipitation and flooding (2016–2017 winter) exemplifies what this precipitation whiplash looks like and what its impact can be: hundreds of roads and other infrastructure throughout California were damaged by floods and mass movements such as landslides. Heavy runoff in the Feather River watershed contributed to the failure of the Oroville Dam spillway, forcing the evacuation of almost a quarter of a million people (Swain et al., 2018). A wet-to-dry whiplash promotes the growth of vegetation that later dries and serves as fuel for wildfires (Williams et al., 2019). Altogether, projections of climate change suggest that California will spend most of the year in a perennial drought, interrupted periodically by large storms that produce heavy precipitation (Allen and Luptowitz, 2017; Gershunov et al., 2019; Huang et al., 2020; Pottinger, 2020). Both droughts and floods have major consequences for the people, environment, and economy of California (discussed in the *Drought* and *Coastal Flooding* chapters).

Tribal Connection 2.2.3

Prolonged droughts followed by heavy floods threaten cultural resources of many California Native American tribes, including the Big Pine Paiute Tribe. *“In addition to wildfire and drought, the region has also faced climate extremes in the form of heavy snowmelt and runoff. In 2023, a season of significant snowfall in the Sierra Nevada was followed by a rapid and intense melt, forcing the community to prepare for possible flooding. [...] Historically, water flowing off the mountains during the spring melt was absorbed by the valley’s meadows, wetlands, and creeks, but with shifts in precipitation timing, land development, and soil health, the ability of the land to buffer these events has weakened. Much of the land where one of our Tribal groups traditionally lived lies directly in a floodplain, placing areas of cultural and ancestral importance at continued risk. These patterns further underscore how the challenges we now face are not isolated or seasonal—they are cumulative, intersecting, and deeply tied to both climate and the long-term legacy of altered land management”* (Big Pine Paiute Tribe, 2026).



As previously mentioned, atmospheric rivers are the source of most of California's water supply. They also cause most of the state's flood damage. Approximately 80% of levee breaches in California's Central Valley are associated with atmospheric rivers in the Categories 3 to 5 magnitude range (Florsheim and Dettinger, 2015; DWR, 2019).

Weaker atmospheric rivers are generally beneficial because they can enhance water supply and snowpack, while stronger atmospheric rivers, especially those occurring after a prolonged duration, can become mostly hazardous because of flooding and associated impacts like landslides (DWR, 2019).

Floods, landslides, avalanches, and post-fire debris following heavy rainfall pose serious risks to human life, infrastructure, and communities (Collins et al., 2020; Hatchett et al., 2017a and 2020). Intense rainfall after a wildfire can produce fast-moving, highly destructive debris flows (USGS, 2021). For example, in January 2018, heavy rainfall over an area recently burned by the Thomas Fire triggered deadly landslides in southern California, causing loss of life and extensive damage (Lukashov et al., 2019). **Figure 2.2.6** shows shallow landslide and debris flow scars in the Tuolumne River Canyon on March 22, 2018, illustrating how extreme precipitation events can rapidly mobilize sediment and cause damage to infrastructure (Collins et al., 2020). More recently, from December 2022 through March 2023, fourteen atmospheric rivers caused flooding and hundreds of landslides, leading to condemned homes, severed lifelines, evacuated communities, and in early 2023 alone a series of storms resulted in 21 deaths and over \$3 billion in losses (DOC, 2023; Castañón, 2024).



Figure 2.2.6. Heavy Rainfall Triggered over 500 Landslides at the Tuolumne River Canyon in 2018.



Source: Collins, et al. (2020), Photo credit: Wayne Hadley



Climate change is increasing both the frequency and magnitude of extremely severe storm sequences capable of causing megaflood events in California (Huang and Swain, 2022). The chances of an extreme 200-year flood event, last seen in the extraordinary “Great Flood” of 1861–1862, are more likely than not to occur within the next 40 years, and multiple occurrences are plausible by 2100 on a business-as-usual greenhouse gas emissions trajectory (Swain et al., 2018). During the Great Flood, flood waters remained throughout the state for months, transforming the land and making roads impassable (Jones, 2019). A storm of this magnitude today would probably lead to considerable loss of life and economic damages approaching a trillion dollars (Swain et al., 2018; USGS, 2011).

What factors influence this indicator?

High year-to-year variability in precipitation is a natural feature of California’s climate. Climate change is intensifying these natural fluctuations, increasing both the frequency and severity of extreme wet and dry conditions. Greenhouse gases (GHGs) like carbon dioxide and methane, as well as solar forcing, contribute to increases in temperature. A warmer atmosphere’s increased capacity to hold and release moisture—about 7% more water vapor for each degree Celsius of warming – leads to precipitation intensification (Swain et al., 2018 and 2025). In addition to GHGs, aerosols also influence precipitation patterns: sulfates tend to enhance winter precipitation, while black carbon can suppress it (Allen et al., 2020; Risser et al., 2024).

Along with interannual variability, California also has seasonal fluctuations. During the summer, California experiences a dry season as atmospheric moisture gets diverted away from the state by dense blobs of air parked over the north Pacific Ocean (also known as a “high pressure zone”). In the southeastern desert regions, however, some monsoonal activity in the summertime may bring thunderstorm precipitation (Corbosiero et al., 2009; WRCC, 2021). Precipitation deficits in winter 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 from 2012 to 2015 (Swain, 2015). During winter, the Pacific high-pressure zone retreats southward, and much of California’s annual precipitation falls during a few large



“atmospheric river” storms (Lamjiri et al., 2018; WRCC, 2021). Very heavy and rare rainfall events are expected to become larger and more frequent across the United States (Swain et al., 2020).

On average, rainfall from atmospheric rivers makes up 79%, 76%, and 68% of all extreme-rainfall accumulations in the North Coast, Northern Sierra, and Transverse Ranges of Southern California, respectively (Lamjiri et al., 2018). Windward slopes of hills or mountains provide the ideal location for atmospheric rivers to produce heavy precipitation in California through a phenomenon called orographic forcing: when air gets pushed up the slope of a mountain range, the water vapor cools and condenses if the air is moist enough, forming clouds and causing heavy precipitation to fall (Ralph, 2019). Precipitation from atmospheric rivers in western North America are expected to become more frequent, heavy, and extreme (Gershunov et al., 2019; Hagos et al., 2016; Polade et al., 2017) due to more moisture in the atmosphere. Although climate change will enhance the amount of precipitation delivered by landfalling atmospheric rivers along the West Coast, the overall frequency of precipitation will decrease as fewer storms not caused by atmospheric rivers are projected (Gershunov et al., 2019).

Most of the water vapor that provides the state’s precipitation comes from the Pacific Ocean. Much of the variability in the state’s precipitation is related to El Niño and La Niña in the tropical Pacific, which are the warm and cool phases of a recurring climate pattern called the El Niño-Southern Oscillation, or ENSO. Climate change may make extreme El Niño and La Niña events become more frequent and stronger by the end of the century (NOAA, 2020), although the specific impacts of ENSO on precipitation in California are highly variable and challenging to predict.

Regarding physical state, precipitation falls as rain or snow depending on the temperature of the air and the ground, the local geography, and the characteristics of the storm itself. Warming temperatures and their influence on a rising snowline (the altitude above which snow remains on the ground) make winter precipitation more likely to fall as rain instead of snow and run off into the ocean or be used by vegetation instead of being stored in reservoirs (Gonzales et al., 2019; Hatchett et al., 2017b;



Huang et al., 2020; Lynn et al., 2020). This higher runoff poses a greater flood risk (Huang et al., 2020).

Technical considerations

Data characteristics

Precipitation totals are tracked by “water year,” from the beginning of the rainy season defined as October 1 through September 30, the end of the dry season. This is more useful than a calendar year in California due to its typically dry summer and wet winter (“Mediterranean”) climate. On average, 75% of the state’s annual precipitation occurs from November through March, with 50% occurring from December through February.

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 is calculated as the statewide value.

Annual precipitation data come from the California Climate Tracker, an operational database tracker for weather and climate monitoring information. This indicator tracks precipitation amount in a “water year”. This operational product, the California Climate Tracker, is updated periodically online at the [Western Regional Climate Center](#) (WRCC). Data, including historical data, is continuously monitored and updated. The data provided here is the data set available as of October 2025 from WRCC with the most up-to-date values for modeled historical data.

Precipitation data were obtained from the Western Regional Climate Center database, which obtains PRISM data using [ACIS web services](#). The PRISM Climate Mapping Program (Oregon State University) is an ongoing effort to produce and disseminate the most detailed, highest-quality spatial climate datasets currently available. PRISM (Parameter-elevation Regressions on Independent Slopes Model) is an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate fine scale (4-kilometer, 2.5 arc-minutes) grid-based estimates of monthly precipitation and temperature from 1895-present. PRISM uses point measurements of climate data and a digital elevation model of terrain and is constantly updated to map climate in the



most difficult situations, including high mountains, rain shadows, temperature inversions, coastal regions, and associated complex meso-scale climate processes.

The methodology for determining the rain/snow trends combined fine-scale gridded precipitation data with coarse-scale freezing level and precipitation data from an atmospheric reanalysis. Snowfall was estimated as a fraction of total precipitation at a high spatial resolution, with output from WRCC's [North American Freezing Level Tracker](#) (NAFLT). For more information about the methods used, see Lynn et al. (2020).

The atmospheric river data were obtained from the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography.

Strengths and limitations of the data

The datasets used in this work underwent 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. PRISM data offers complete coverage across the state for every month of the record. However, limitations include the bias of station data toward populated areas and quality control processes are more limited in remote or high terrain areas. The results cited here offer a hybrid using both gridded and station data, considered more robust than either data set used independently (Abatzoglou et al., 2009).

An advantage of the rain/snow approach used by Lynn et al. (2020) is that the NAFLT can be updated as higher resolution gridded data products become available. This type of analysis can play an important role in developing and implementing adaptive strategies for water management. However, the approach relies on interpolated observational data which are sparse in mountainous regions and may not fully reflect snowline variability in complex terrain.



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