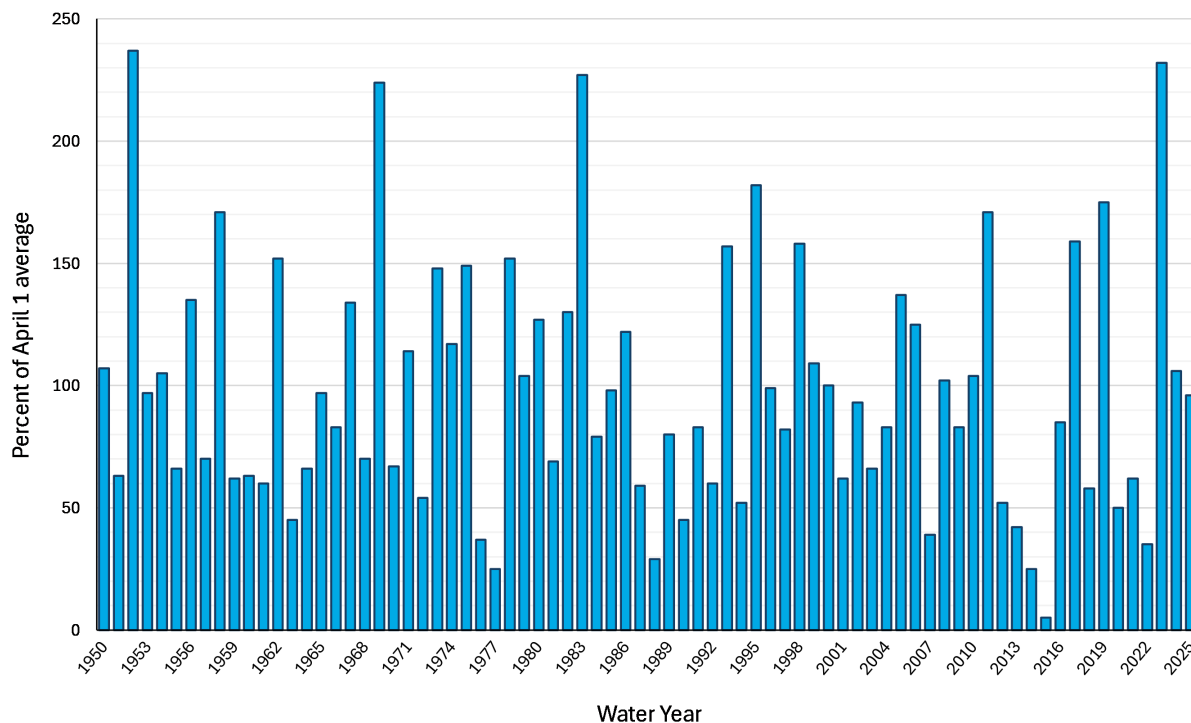


3.12 Snow-Water Content

The amount of water stored in the state's snowpack varies greatly from year to year, reflecting the variability in the amount and form of precipitation over California's mountain areas. There has been a small long-term decline across the state's snowpack since measurements began in the 1950s, as rising temperatures shift precipitation from snow to rain and cause earlier snowmelt. Significant, long-term declines in snow-water content occur in the Sierra Nevada and Cascade mountains at elevations below 2500m.

Figure 3.12.1. Statewide April 1 Snow-Water Equivalent (SWE).



This graph shows annual measurements of snow-water equivalent (SWE, also referred to as snow-water content) —the amount of water stored in the snow—on April 1, when California's snowpack typically reaches its peak. The historical average SWE on April 1, based on the water years 1991-2020, is about 28 inches. Source: DWR (2026a)



What does the indicator show?

This indicator tracks the amount of water stored in California's snowpack, which typically accumulates from October to March in the Sierra Nevada and southern Cascade Mountains. Although some of this water will be lost to direct evaporation and transpiration, most will be available to percolate into the soil or runoff (see the *Snowmelt Runoff* chapter) into streams and rivers as temperatures rise in spring and summer. California's snowpack has historically stored up to 15 million acre-feet of water – about 35% of the state's reservoir capacity. Peak snow-water equivalent (SWE, the depth of water that would cover the ground if the snowpack were liquid) typically occurring between mid-March and mid-April. April 1 measurements are commonly used to estimate how much water will be released as snowmelt later in the year, though timing can vary by location and year (NRDC, 2014).

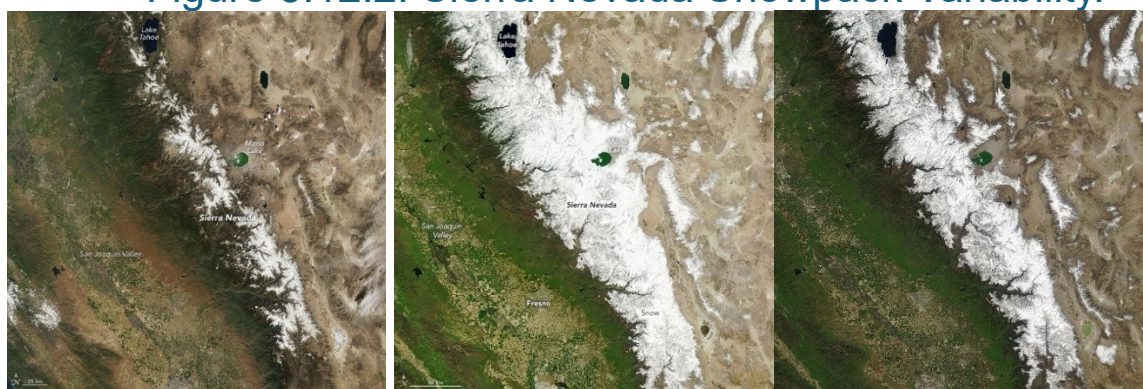
Figure 3.12.1 presents this amount of liquid water measured on April 1 each year based on snow course measurements. Snow courses are long-term monitoring locations where SWE is measured by weighing cores of snow pulled from the entire depth of the snowpack at a given location. The measurements represent snowpack conditions at a given elevation in each area. Statewide snowpack is highly variable, with extreme high and low snow years. There has been a small overall decline since snowpack data was first collected in the 1950s. SWE ranged from more than 200% of average in 1952, 1969, 1983, and 2023, to 5% in 2015 during the multi-year drought (2012 to 2016).

The past decade included years that were among the lowest (2013, 2014, 2015 and 2022) and the highest (2011, 2017, 2019, and 2023) on record. Maps of Sierra Nevada snowpack in low (2015), high (2023), and average (2024) snow years are shown in **Figure 3.12.2**. Snowpack in California can swing between "snow droughts" and "snow deluges". Snow droughts occur when SWE is unusually low (Cooper et al., 2016). It can result from either below-average winter precipitation ("dry" snow drought) or from near-normal precipitation when warmer temperatures limit snowpack accumulation ("warm" snow drought) (Harpold et al., 2017). A warm and wet snow drought occurred in the Sierra Nevada in 2026, when hot March temperatures and high-elevation rain



erased the Sierra Nevada snowpack months ahead of schedule (DWR, 2026c). Snow droughts are already more common across the western United States and are projected to become warmer and wetter in future years (Schmitt et al., 2024). On the other end of the spectrum are snow deluges - years of exceptionally heavy snowfall, such as 2023. These events require the unlikely pairing of both cool and wet conditions, and climate projections suggest they will become less frequent as the region warms (Marshall et al., 2024).

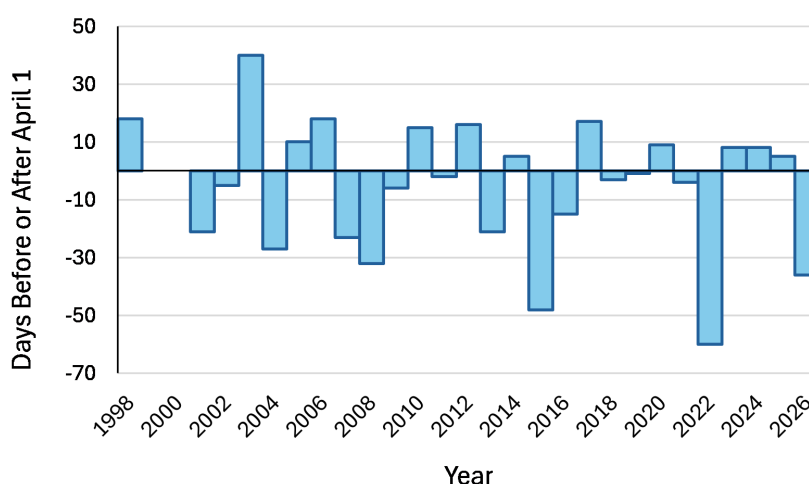
Figure 3.12.2. Sierra Nevada Snowpack Variability.



The following images are taken from satellite data that show the spatial extent of snowpack in late March and early April, around the time when snowpack in Sierra Nevada generally peaks: March 31, 2015 (left, the lowest snow year on record), April 6, 2023 (middle, a high snow year), and April 2, 2024 (right, an average snow year). Source: [NASA Earth Observatory](https://earthobservatory.nasa.gov/)

As shown in **Figure 3.12.3**, the California Cooperative Snow Survey recently analyzed peak SWE through the 21st century and found that the average remains close to April 1, but with high variability and earlier peaks in 2015, 2022, and 2026.

Figure 3.12.3. Peak Statewide SWE Relative to April 1.



The figure shows the number of days before or after April 1, the peak statewide SWE occurred that year. Negative values represent number of days before April 1, and positive values represent number of days after April 1. Source: [California Cooperative Snow Survey](#)

Why is this indicator important?

California's snowpack acts as a natural reservoir, storing water in the form of snow during the colder months and gradually releasing it as water as it melts during the warmer months. This meltwater feeds into rivers and streams, providing a significant portion of the state's water supply for agricultural, urban, and industrial use (DWR, 2026b). Snowmelt gradually releases cold freshwater into lakes and rivers (see the *Lake Water Temperature* and *Salmon River Water Temperature* chapters), and many aquatic ecosystems in California depend on this seasonal influx (Sadro et al., 2019). In times of low precipitation or reduced water availability, the gradual melt of the snowpack ensures a relatively steady downstream flow, helping to mitigate the impact of drought on water availability (see the *Drought* chapter). Snowfall also creates opportunities for winter sports such as skiing, snowboarding, and snowshoeing, which



contribute significantly to the state's tourism industry, bringing in revenue and supporting local economies (DWR, 2026b).

Tracking SWE provides critical information for managing water supply, mitigating drought, preventing floods, and maintaining ecosystem health. To reduce flood risk, water managers keep space in reservoirs during winter to capture storm runoff. Around April 1, operations shift to storing streamflow for summer use, relying on the snowpack to release water gradually. In high-snow years like 2017 and 2019, early snowmelt in March or April can ease pressure on reservoirs. Whiplash between extreme wet and dry conditions, such as from extreme drought to a record-setting snowpack such as in 2022 to 2023, further complicates water management and flood risk (Jimenez Arellano et al., 2025). Forecasts based on SWE, such as the California Department of Water Resources (DWR)'s Bulletin 120, are critical for managing this balance. Tracking snowpack is also key to assessing drought risk. Low SWE in winter or spring can signal water shortages in summer (NRDC, 2014). Importantly, today's managed water systems were designed for past climate conditions. Adapting to a warming climate will require improved monitoring, forecasting, and integrated water management approaches (Siirila-Woodburn et al., 2021).

What factors influence this indicator?

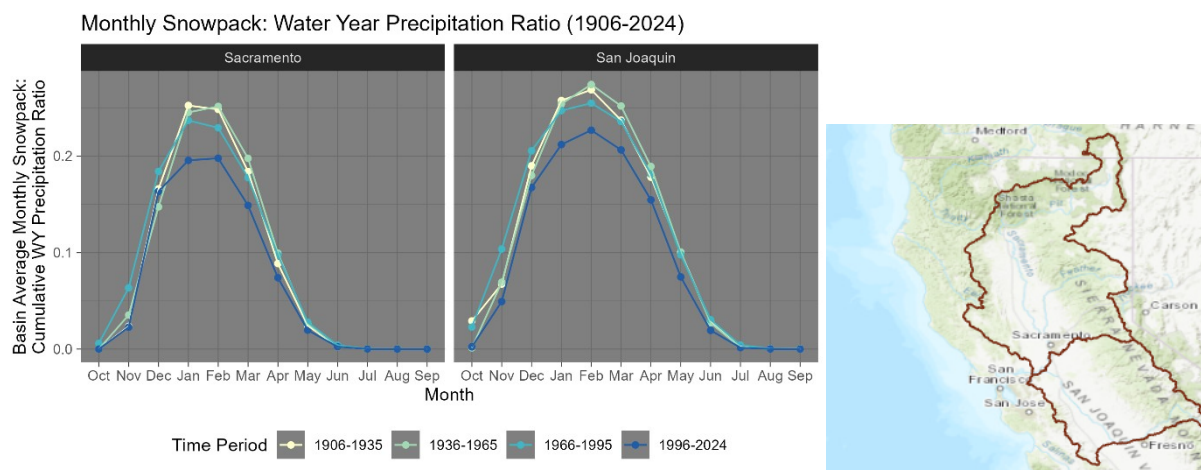
Snow forms when air temperatures are near or below freezing (0°C or 32°F) and the ground is cold enough to support accumulation. Colder air produces lighter, drier snow with low water content, while slightly warmer conditions create heavier, wetter snow with more liquid water. Although warmer snow can hold more water, the overall number of days cold enough for snowfall is declining, ultimately reducing the total snow-water stored over a season (UC Davis, 2018).

Warmer temperatures accelerate snowmelt, reducing SWE by the end of the season, especially if precipitation falls as rain instead of snow. Late-season precipitation that falls as rain on snow accelerates snowmelt, resulting in rapid snowmelt that can lead to flooding (Katz et al., 2023; Reis et al., 2026). **Figure 3.12.4** shows that a smaller proportion of annual precipitation is stored as snowpack in recent decades compared with the early 20th century. This pattern is evident in both the Sacramento and San



Joaquin and reflects shift from snowfall toward rainfall as temperatures warm (see the *Precipitation* chapter).

Figure 3.12.4. Ratio of Monthly SWE to Total Precipitation.



The graphs show the ratio of monthly SWE compared to cumulative water year precipitation for four time periods: 1906-1935, 1936-1965, 1966-1995, and 1996-2024. Values are spatial averages across the San Joaquin and Sacramento watersheds (outlined in map on the right). Monthly values represent the average annual fraction of water year (WY) precipitation stored as snow during each time period. Source: Analyses by Christine Albano (2026). Data is from the USGS ScienceBase-Catalog.

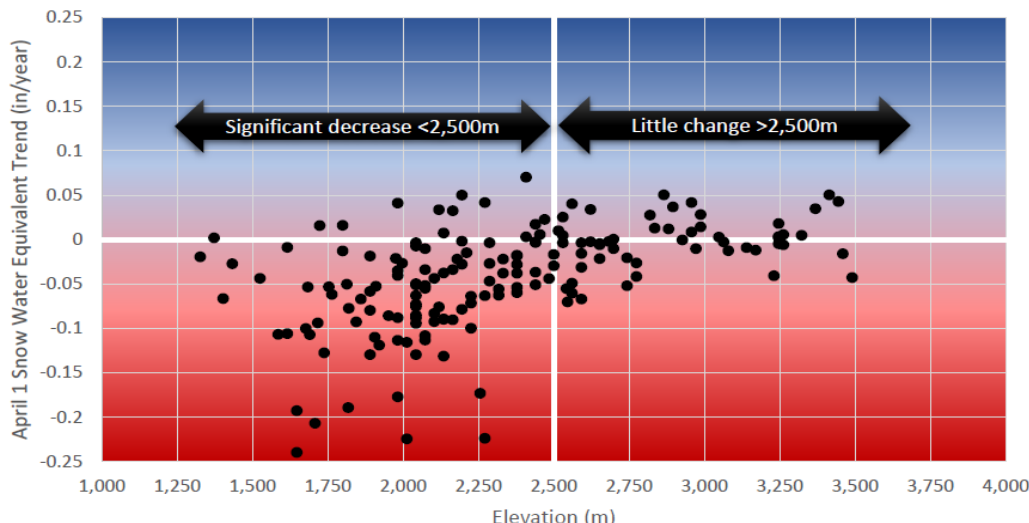
Across western North America, more than one-third of long-term snow monitoring stations show evidence of earlier snowmelt, often occurring before peak snow accumulation is reached (Musselman et al., 2021). In addition, with unabated warming, more than half of precipitation in the Sierra Nevada is projected to fall as rain instead of snow (Beltran-Peña et al., 2025). By late 21st century, snow accumulation in the Sierra Nevada is projected to decline to less than half of the historical average, with the greatest snow loss at mid elevations during fall and spring (Shulgina et al., 2023).

Local characteristics play a role in regional patterns of snowpack. Higher elevations are generally colder, so they often accumulate more snow than lower elevations. The influence of elevation is evident in an analysis of snowpack trends in the Sacramento River, San Joaquin River, and Tulare Lake Basins (Figure 3.12.5; Riddlebarger et al., 2021). The snow courses that make up the northern Sierra group in Figure 3.12.5 are



at lower elevations (average 6,900 feet) compared to the southern group (average 8,900 feet). In the past 70 years, the proportion of precipitation as snow has decreased at the rate of 4% per decade over lower and middle elevation regions of the northern Sierra Nevada, while the highest elevations of the southern Sierra Nevada, where temperatures remain at or below 0°C during winter and spring, showed no declines (Lynn et al., 2020). Consistent with this pattern of lower (and thus warmer) elevations being more susceptible to warming impacts on snowpack, an analysis of April SWE and temperature from 1985 to 2016 found that the northern Sierra Nevada to be more vulnerable to warming than the southern region (Huning and AghaKouchak, 2018). Over the past decade, the average snow level (altitude where precipitation changes from snowfall to rain) along the western slope of the northern Sierra Nevada has risen over 1,200 feet (Hatchett et al., 2017).

Figure 3.12.5. Trends on April 1 SWE at Sierra Nevada and Cascade Mountains Snow Courses.



The figure shows 60-year trends in SWE at each snow course. Trends are represented by each dot. Snowpack has declined at 78% (129 of 166) of the snow courses: snow courses at elevations below 2,500 meters showed negative trends at an overall average of - 0.07 inch/year; at elevations higher than 2,500 meters, the trends clustered between -0.05 and +0.05 inch/year. Source: Riddlebarger et al. (2021)



Warming temperatures are driving snowpack losses across the western United States, beyond what would be expected from natural variability alone (Siler et al., 2019).

Reduced snowpack is observed across all months, states, and climates, especially in the spring, in the Pacific states, and in locations with mild winter climate (Mote et al., 2018). California's snowpack trends are consistent with these declines (Mote et al., 2018; Musselman et al., 2021; Siirila-Woodburn et al., 2021). Warm daily maximum temperatures in March and April in the Sierra Nevada are associated with earlier peak snow mass of 0.6 days per decade since 1930, as well as earlier snowmelt and lower SWE (Kapnick and Hall, 2010). Continued warming will likely lead to less snowpack if precipitation does not significantly increase (Knowles and Cayan, 2004), while increased precipitation could partially offset snowpack losses in some higher-elevation areas.

To a lesser extent, SWE may be influenced by the amount of solar radiation reaching the snowpack in each season, which, in turn, depends on cloudiness and timing of the beginning of the snowmelt season (Lundquist and Flint, 2006). Cloudiness decreases solar radiation on the snowfields and would tend to result in less wintertime snowmelt and thus more SWE left by April 1 (the opposite would occur if cloudiness declined in the future).

A potential confounding factor in the variation and trends in snowpack is the effect of dust and air pollutants (including black carbon, a component of soot) on both the initial formation of mountain snowpack and on snowmelt timing. Field measurements and modeling have shown that the presence of dust in the atmosphere, including dust from Asia and the Sahara carried to California by high-altitude winds, may increase snowfall over the Sierra Nevada by serving as ice nuclei, which in turn could contribute to increased snowpack (Ault et al., 2011; Creamean et al., 2013). Recent studies in the Colorado River Basin have helped to quantify important influences on snowmelt timing and, ultimately, amounts that are due to springtime snow albedo (reflectivity) changes associated with dust (mostly from within the region) falling onto snow surfaces across the Western US (Painter et al., 2010). Light-absorbing particles such as black carbon, which in burned forests are deposited onto the snow surface, have been measured in



the Sierra Nevada snowpack at concentrations sufficient to increase surface temperatures and increase snowmelt (Hadley et al., 2010; Huang et al., 2022).

Technical considerations

Data characteristics

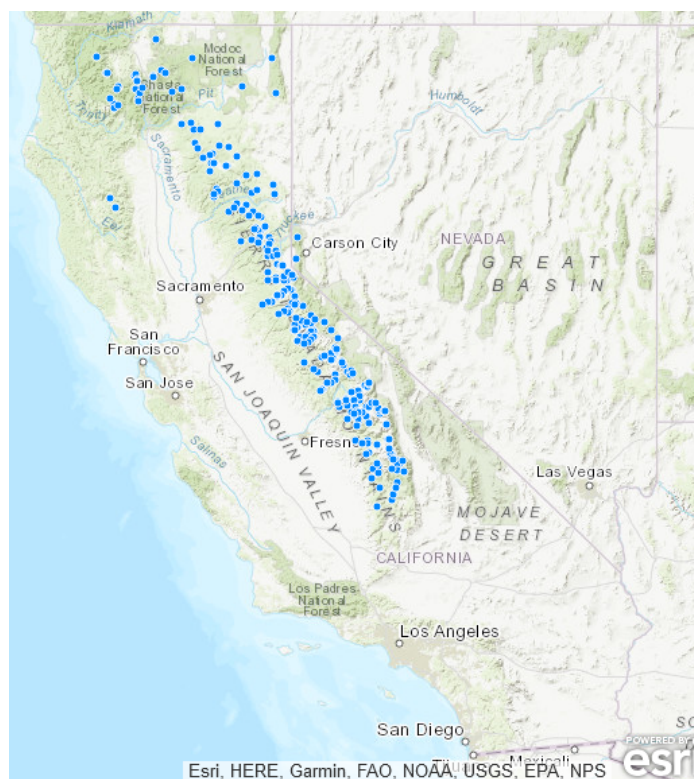
Statewide SWE is based on observations from permanent snow courses. At these locations, observers collect and weigh snow cores that extend through the full depth of the snowpack. Since the 1930s, within a few days of the beginning of each winter and spring months, measurements have been taken along snow course locations that represent snowpack conditions at a given elevation in each area.

SWE represents the amount of water that would result if the snowpack melted completely. Manual measurements are typically collected near the first of each month from January through May. The April 1 survey is particularly important because it generally occurs near the seasonal maximum snowpack accumulation. The statewide values are based on measurements taken at about 260 snow course stations from the Trinity Alps and Mount Shasta in northern California, and throughout the Sierra Nevada down to the Kern River basin in the south ([Figure 3.12.6](#)).

Measurements are taken by skiing or flying to remote locations and extracting 10 or more cores of snow along ¼ mile-long pre-marked “snow course” lines on the ground. The depth of snow and the weight of snow on the cores are measured. The weights are converted to a depth of water that would result if snow melted completely, and the results from all the measurements at the snow course are averaged to arrive at estimates of the SWE at that site (Osterhuber, 2014). More than 50 state, federal and private entities have pooled their efforts in collecting snow data from over 250 snow courses in California (see [Figure 3.12.6](#) for locations).



Figure 3.12.6. Location of Snow Courses.



Map shows areas where SWE is measured during regular snow surveys. Source: [California Cooperative Snow Survey](#)

Data from monthly snow surveys are supplemented by daily information from an automatic snow sensor network (often called snow pillows), developed and deployed over the last 30 to 40 years. They serve as a valuable check on the representativeness and accuracy of the snow-course measurements. The snow sensors measure the accumulation and melting cycles in the snowpack, providing data on the effect of individual storms or hot spells. In addition to tracking changes during the snow accumulation season, snow sensor data help greatly in forecasting water volumes involved in the late-season filling of reservoirs.

SWE data for snow courses and snow sensors can be downloaded from the Department of Water Resources' [California Data Exchange Center](#).



Strengths and limitations of the data

The measurements are relatively simple, and the methods have not changed since monitoring started. Averaging 10 or more measurements at each course yields relatively accurate and representative results for each survey. However, snow course measurements are collected at specific monitoring locations and may not fully capture variability across all elevations, terrain types, and snow conditions throughout California's mountain regions. Furthermore, averaging measurements from all sensors obscures localized changes occurring at specific locations.

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