

Climate Change in Colorado: Recent Trends, Future Projections and Impacts

An Update to the Executive Summary of the 2014 Report

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[Text which has been revised or added is highlighted.]

Summary

In the past 30 years, Colorado's climate has become substantially warmer. The recent warming trend in Colorado is in step with regional and global warming that has been linked to increasing atmospheric concentrations of greenhouse gases. Annual precipitation, which has high natural variability, has not seen a statewide trend over that period. However, some drought indicators have worsened due to the warmer temperatures.

As greenhouse gases and other human effects on the climate continue to increase, Colorado is expected to warm even more by the mid-21st century, pushing temperatures outside of the range of the past century. The outlook for future precipitation in Colorado is less clear; overall increases or decreases are possible. The risk of decreasing precipitation appears to be higher for the southern parts of the state.

The future warming is projected to generally reduce Colorado's spring snowpacks, cause earlier snowmelt and runoff, reduce annual streamflow volumes, and increase the water use by crops, landscaping, and natural vegetation.

Observed climate trends in Colorado

- Statewide annual average temperatures have increased by about 2°F over the past 30 years, and this trend is statistically discernible from the year-to-year variability. Four of the six warmest years on record (since 1895) have occurred in the period from 2012 through 2017. Temperatures have increased in all seasons. At the local scale, warming trends have been observed for most parts of the state.
- Warming temperatures alone have a widespread impact on the water cycle. A warmer atmosphere has greater "thirst" (higher vapor-pressure deficits) and tends cause higher evaporation from snowpacks, soils, vegetation, and surface water.

- No significant long-term trends in annual precipitation have been detected for Colorado, even with the relatively dry period since 2000. The high variability in precipitation means that trends have to be large to be statistically discernible.
- Snowpack, as measured by April 1 snow-water equivalent (SWE), has been mainly below-average since 2000 in all of Colorado's river basins, and it is likely that warmer winter and spring temperatures are leading to an overall decline in the spring snowpack. However, the likely warming-induced changes in Colorado's snowpack have been modest than those in other regions of the Western US (Sierra Nevada, Cascades, Northern Rockies) where the winter climate is warmer than in Colorado (Lute et al. 2015, Mote et al. 2018).
- While the high variability makes it very difficult to detect trends in streamflow, there is evidence that warmer temperatures have already caused some reduction in annual streamflows in Colorado. Recent analyses by McCabe et al. (2017), Udall and Overpeck (2017), and Woodhouse et al. (2016) suggest that the below-average streamflows in the Upper Colorado River Basin since 2000 are partly attributable to the above-normal temperatures over that period.
- The timing of snowmelt and peak runoff has shifted earlier in the spring by 1–4 weeks in most of Colorado's river basins and watersheds over the past 30 years, due to the combination of lower snowpacks since 2000, the warming trend in spring temperatures, and enhanced solar absorption from dust-on-snow events.
- The Palmer Drought Severity Index (PDSI) shows a trend towards more severe soil-moisture drought conditions in Colorado over the past 30 years, reflecting the combined effect of the warming trend and below-average precipitation since 2000.
- No long-term trends in heavy or extreme precipitation events are detectable in statewide composites of multiple station records. The evidence suggests that there has been no statewide trend in the magnitude of flood events in Colorado.
- Tree-ring records and other paleoclimate indicators for Colorado show multiple droughts prior to 1900 that were more severe and sustained than any in the observed record. These droughts would be even more severe if they recurred in a warmer climate.

Linking changes in Colorado to global changes

- The global climate system has warmed substantially since 1900, particularly in the past 30 years, as evidenced by increased surface, atmospheric, and ocean temperatures; melting glaciers and ice sheets; rising sea levels; and increased atmospheric water vapor.
- These global changes have been attributed mainly to anthropogenic (human-caused) influences, primarily the increase in greenhouse gases in the atmosphere to the highest levels in at least 800,000 years. Natural sources of climate variability alone cannot explain these changes.

- The statewide warming in Colorado is plausibly linked to anthropogenic influences, but definitive attribution at this spatial scale is difficult.
- Colorado's annual precipitation has not exhibited recent trends or variability that might be attributed to anthropogenic climate change.
- Anthropogenic climate change has likely increased the severity of recent drought conditions in the western U.S., including Colorado, due to the influence of the warming trend on snowpacks, streamflows, and soil moisture.
- Despite the lack of observed trend, it is still plausible that recent extreme precipitation events in Colorado, such as in September 2013, were influenced by anthropogenic climate change (Trenberth et al. 2015). Warmer temperatures globally have increased atmospheric water vapor, tending to make more moisture available to the weather mechanisms associated with extreme precipitation.

Projections of Colorado's future climate

- All future projections from global climate models (GCMs) indicate continued warming in Colorado over the next several decades, regardless of the greenhouse-gas emissions scenario. Scenarios assuming higher emissions of greenhouse gases lead to greater warming.
- The statewide average annual temperatures are projected to warm by +2.5°F to +5°F by 2050 relative to a 1971–2000 baseline under a medium-low emissions scenario (RCP 4.5). Under a high emissions scenario (RCP 8.5), the projected warming is larger at mid-century (+3.5°F to +6.5°F), and much larger later in the century as the two scenarios increasingly diverge.
- Summer temperatures are projected to warm slightly more than winter temperatures. Typical summer temperatures by 2050 are projected under RCP 4.5 to be similar to the hottest summers that have occurred in past 100 years.
- Climate model projections show less agreement regarding future precipitation change for Colorado. The individual model projections of change by 2050 in statewide annual precipitation under RCP 4.5 range from -5% to +6%. Projections under RCP 8.5 show a similar range of potential future changes (-3% to +8%).
- Nearly all of the climate model projections indicate increasing winter precipitation by 2050. There is weaker consensus among the projections regarding precipitation in the other seasons, but most indicate less precipitation falling during the growing season (May-September).
- Most projections of future Colorado hydrology show decreases in average annual streamflow for Colorado's river basins by mid-century, by up to -30%, due mainly to the detrimental impact of warmer temperatures on streamflow. Some projections show large enough increases in precipitation to overcome the impact of warming, leading to increases in runoff, by up to +10%.

- Water-supply systems and aquatic ecosystems are most stressed by droughts, not average conditions. Given the same deficit in precipitation, a future drought will have greater impacts than a 20th-century drought, including lower streamflows, due to the warmer temperatures.
- The peak of the spring runoff is projected to shift 1–3 weeks earlier by the mid-21st century due to warming. Late-summer flows are projected to decrease substantially as the peak shifts earlier. These changes in the timing of runoff are more certain than the changes in the annual volume of streamflow.
- Nearly all projections of Colorado’s spring snowpack (April 1 SWE) show declines for the mid-21st century due to the projected warming, with most of the projected changes ranging from -5% to -20%. The declines result from a portion of cool-season precipitation falling as rain instead of snow, and greater sublimation and snowmelt during the winter and early spring (Lute et al. 2015).
- All climate projections indicate that heat waves will substantially increase in frequency and severity in Colorado as the summer climate becomes warmer. A recent analysis of the climate model projections (Saunders et al. 2016) indicates that the average number of days per year over 95 degrees F along the urban Front Range would increase 4-fold to 7-fold by the mid-21st century compared to the late 20th century.
- The risk of severe, sustained soil-moisture drought in Colorado and the West during the 21st century is projected to be much higher than during the 20th century, due mainly to warmer temperatures causing enhanced drying of soils (Cook et al. 2015).
- With warmer temperatures and a “thirstier” atmosphere, the water required by irrigated crops in Colorado is projected to increase, as is urban outdoor water demand. The increase in water demand depends on the amount of warming and changes in summer precipitation, but generally ranges from +5% to +30% by mid-century. These projected increases assume no changes in the crop type or the urban greenery.
- Several studies have used the climate model projections, combined with fire weather and fuels modeling, to assess future changes in wildfire in Colorado and the Rocky Mountain West. These studies consistently indicate that by the mid-21st-century, the fire season will be longer, the annual area burned will be much greater, and the risk of very large wildfires will be much higher, than in recent decades.
- Most climate model projections indicate that extreme precipitation events will become more frequent in the future in Colorado, consistent with global trends and projections. A recent study (Janssen et al. 2014) suggests that extreme rainfall events of the magnitude that now occur every 5 years in Colorado will instead occur every 3 years in 2050.

Primary reference (unless otherwise noted):

Lukas, J., Barsugli, J., Doesken, N., Rangwala, I., and K. Wolter (2014). Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A report for the Colorado Water Conservation Board by the Western Water Assessment. 114 pp.

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