Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation

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The Colorado Climate Report is a synthesis of climate change science important for Colorado's water supply. It focuses on observed trends, modeling, and projections of temperature, precipitation, snowmelt, and runoff. The report summarizes Colorado-specific findings from peer-reviewed regional studies, and presents new graphics derived from existing datasets. The following are highlights from the Report.

The scientific evidence is clear: the Earth's climate is warming. Multiple independent measurements confirm widespread warming in the western United States. In Colorado, temperatures have increased by approximately 2ºF between 1977 and 2006 (Figure 1a). Increasing temperatures are affecting the state's water resources.

Temperature & Precipitation

Climate models project Colorado will warm by 2.5ºF by 2025 and 4ºF by 2050, relative to the 1950–99 baseline. Mid-21st century summer temperatures on the Eastern Plains of Colorado are projected to shift westward and upslope, bringing into the Front Range temperature regimes that today occur near the Kansas border (Figure 1b).

Summers are projected to warm more than winters. Projections suggest that typical summer monthly temperatures will be as warm or warmer than the hottest 10% of summers that occurred between 1950 and 1999 (Figure 1c).

Changes in the water cycle will be the delivery mechanism for many impacts of climate change.

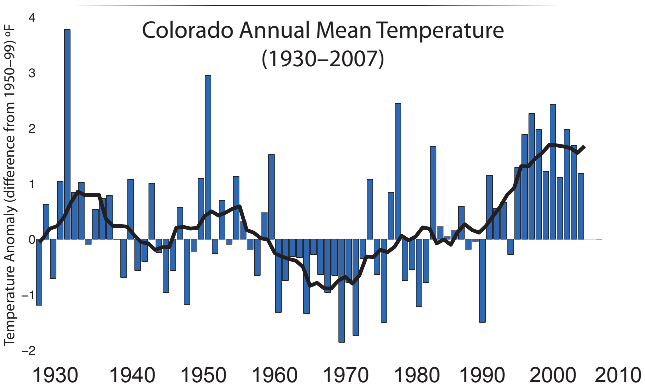

Figure 1a. Annual temperature departures are shown as blue bars relative to a 1950–99 reference period. The 10-year moving average of available data (black curve) highlights low frequency variations in the record. Warm periods occurred in Colorado in the 1930s and 1950s, followed by a cool period in the 1960s and 1970s. Since about 1970, there has been a consistent upward trend in the 10-year average.

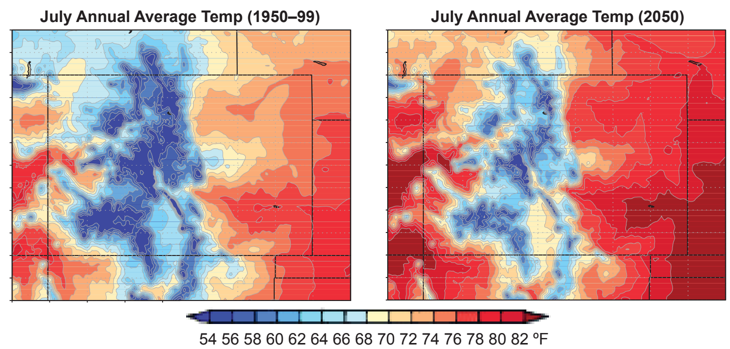

Figure 1b. For July, the temperatures on the Eastern Plains have moved westward and upslope, such that the temperature regime near the western Kansas border has reached the Front Range by 2050.

Changes in the quantity and quality of water may occur due to warming even in the absence of precipitation changes.

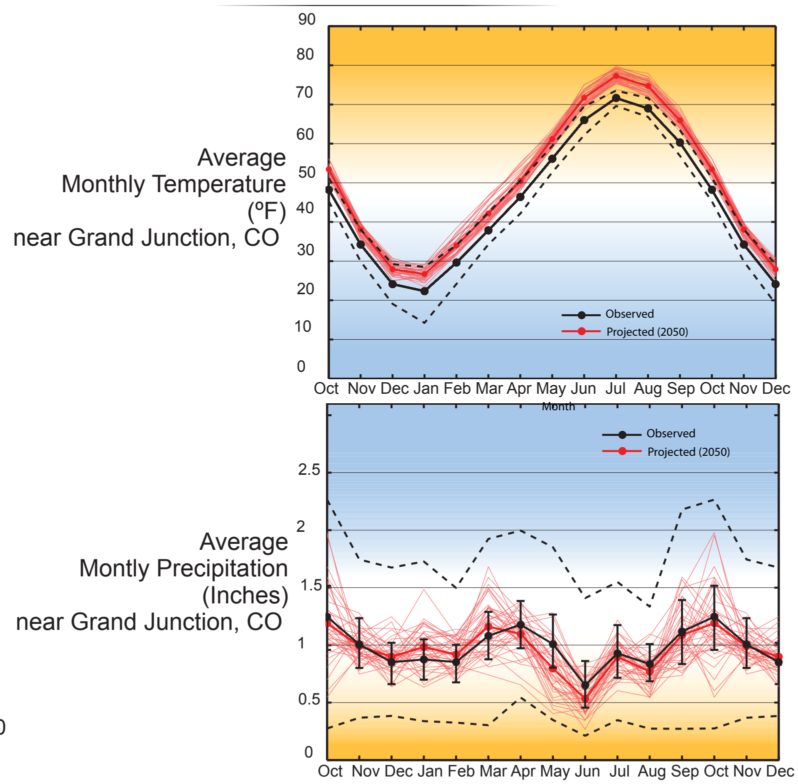

Figure 1c. The monthly average (solid black) and 10th and 90th percentile values (dashed black lines) of temperature (top) and precipitation (bottom) are based on observations (1950–99). Projected monthly climatologies (thin red lines) are from the multi-model ensemble for the 20-year period centered on 2050. Average of the projections is shown as a heavy red line.

The Intermountain West Climate Summary is published monthly by Western Water Assessment, a joint project of University of Colorado and NOAA/ESRL Physical Sciences Division; researching water, climate and societal interactions.

No consistent long-term trends in annual precipitation have been detected in all parts of Colorado (Figure 1d). Variability is high, which makes detection of trends difficult. Climate model projections do not agree whether annual mean precipitation will increase or decrease by 2050.

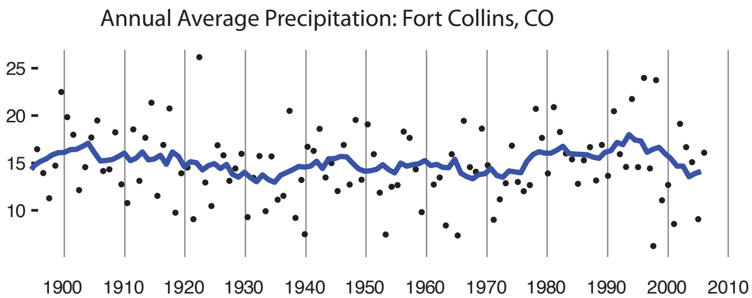

Figure 1d. Water year precipitation (inches) at station in Fort Collins, CO. Overall long-term trends are not detectable here, or at eight other locations (Steamboat Springs, Akron, Grand Junction, Cheyenne Wells, Montrose, Rocky Ford, Trinidad and Lamar) in Colorado. The 10-year moving average is shown to emphasize decadal variations. Data for other locations are shown in the Report.

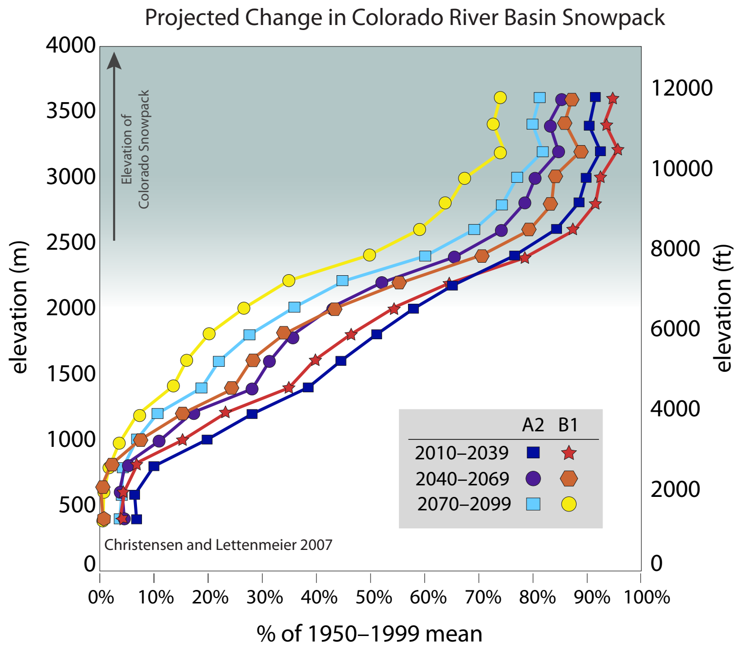

Figure 1e. The data show average snowpack declines throughout the cold season, and are a function of both the snow water equivalent and the amount of time snow is on the ground. The downscaled projections from 11 climate models for the 30-year average centered on 2025, 2055, and 2085 are shown for the B1 and A2 emissions scenarios (see Report for further details). Most of the snowpack in Colorado that feeds the Colorad River lies above 2500 m (8200 ft) in elevation.

Snowpack

Most of the reduction in snowpack in the West has occurred below about 8200 ft. However, most of Colorado's snowpack is above this elevation, where winter temperatures remain well below freezing.

Projections show a precipitious decline in lower-elevation (below 8200 ft) snowpack across the West by the mid-21st century. Modest declines are projected (10–20%) for Colorado's high-elevation (above 8200 ft) snowpack (Figure 1e).

Streamflow

Between 1978 and 2004, the spring pulse (the onset of streamflows from melting snow) in Colorado shifted earlier by two weeks. Several studies suggest that shifts in timing and intensity of streamflows are related to warming spring temperatures. The timing of runoff is projected to shift earlier in the spring, and late-summer flows may be reduced.

Recent hydrology projections suggest declining runoff for most of Colorado's river basins in the 21st century. However, the impact of climate change on runoff in the Rio Grande, Platte, and Arkansas Basins has not been studied as extensively as the Colorado River Basin.

For the Upper Colorado River Basin, multi-model average projections suggest decreases in runoff ranging from 6% to 20% by 2050 compared to the 20th century average, although one statistical streamflow model projects a 45% decline by 2050 (Figure 1f).

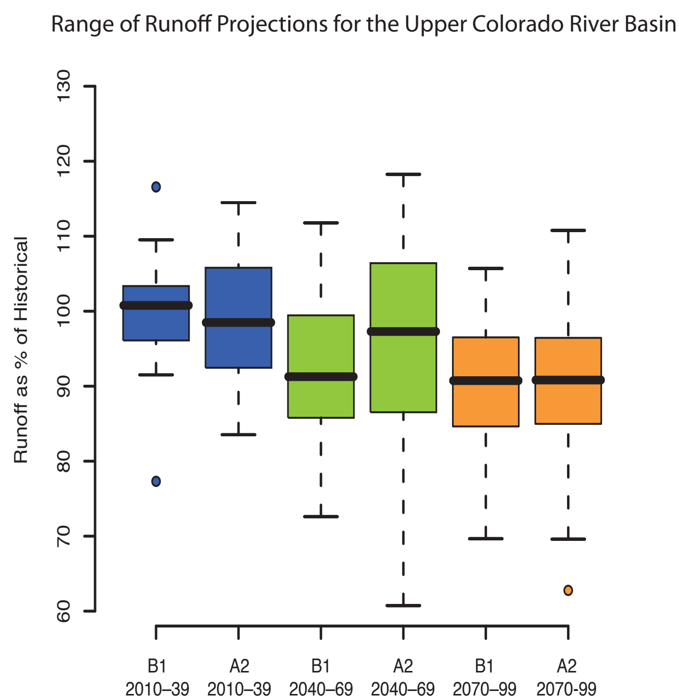

Figure 1f. Box-and-whiskers symbols represent the 5th, 25th, 50th, 75th, and 95th percentiles of the data; outliers are shown by circles. projections are shown for the SRES B1 and A2 emissions scenarios for 30-year averages centered on the years 2025, 2055, and 2085. Changes are relative to 1950–2000 averages. The range of results come from different climate model formulations and from model-simulated climate variability.

A synthesis of the findings in this report suggests a reduction in total water supply by the mid-21st century.

Drought

Throughout the West, less frequent and less severe drought conditions have occurred during the 20th century than revealed in the paleoclimate records over the last 1000 years (Figure 1g).

Precipitation variations are the main driver of drought in Colorado and low Lake Powell inflows, including the drought of 2000–07, and these variations are consistent with the natural variability observed in long-term and paloeoclimate records.

However, warming temeperatures may have increased the severity of droughts and exacerbated drought impacts.

The Report is divided in six sections and includes an Executive Summary, Glossary, List of Resources. An online Appendix will be available soon (http://wwa.colorado.edu). Also included in the Report is an overview of climate models that focuses on how climate projections are developed. This section is intended to provide background for the reader about the the theories behind model development, and the relationship among scenarios, models, and climate projections. Global climate models do not represent the complexity of Colorado's topography. Researchers use techniques such as "downscaling" to study processes that matter to Colorado water resource managers. Several projects are underway to improve regional models.

Reconstructed Streamflow for the Colorado River at Lees Ferry

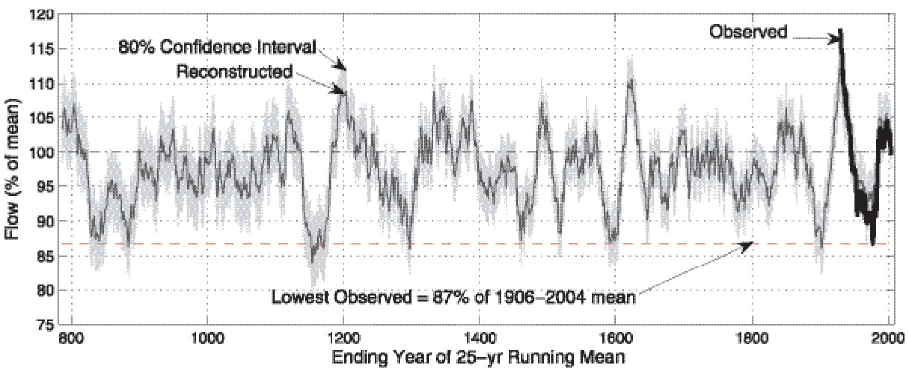

Figure 1g. Reconstructed streamflow (five-year moving average, with 80% confidence interval shown as gray band) compared with observed natural flow (five-year moving average in black). The severity of the 2000–04 drought was probably exceeded at least once in the previous 500 years. (from Meko et al. 2007)

Climate change will affect Colorado's use and distribution of water. Water managers and planners currently face specific challenges that may be further exacerbated by projected climate change.

Issues	Observed and/or Projected Change
Water demands for agriculture and outdoor watering	Increasing temperatures raise evapotranspiration by plants, lower soil moisture, alter growing seasons, and thus increase water demand.
Water supply infrastructure	Changes in snowpack, streamflow timing, and hydrograph evolution may affect reservoir operations including flood control and storage. Changes in the timing and magnitude of runoff may affect functioning of diversion, storage, and conveyance structures.
Legal water systems	Earlier runoff may complicate prior appropriation systems and interstate water compacts, affecting which rights holders receive water and operations plans for reservoirs.
Water quality	Although other factors have a large impact, "water quality is sensitive both to increased water temperatures and changes in patterns of precipitation" (CCSP SAP 4.3, p. 149). For example, changes in the timing and hydrograph may affect sediment load and pollution, impacting human health.
Energy demand and operating costs	Warmer air temperatures may place higher demands on hydropower reservoirs for peaking power. Warmer lake and stream temperatures may affect water use by cooling power plants and in other industries.
Mountain habitats	Increasing temperature and soil moisture changes may shift mountain habitats toward higher elevation.
Interplay among forests, hydrology, wildfires, and pests	Changes in air, water, and soil temperatures may affect the relationships between forests, surface and ground water, wildfire, and insect pests. Water-stressed trees, for example, may be more vulnerable to pests.
Riparian habitats and fisheries	Stream temperatures are expected to increase as the climate warms, which could have direct and indirect effects on aquatic ecosystems (CCSP SAP 4.3), including the spread of in-stream non-native species and diseases to higher elevations, and the potential for non-native plant species to invade riparian areas. Changes in streamflow intensity and timing may also affect riparian ecosystems.
Water- and snow-based recreation	Changes in reservoir storage affect lake and river recreation activities; changes in streamflow intensity and timing will continue to affect rafting directly and trout fishing indirectly. Changes in the character and timing of snowpack and the ratio of snowfall to rainfall will continue to influence winter recreational activities and tourism.

On the Web

- See the full report: http://wwa.colorado.edu
- For more information: email wwa@noaa.gov

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