

RECENT AND PROJECTED ARIDITY IN THE SOUTHWESTERN UNITED STATES

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This information brief summarizes and synthesizes adaptation implications from research supported by the Southwest Climate Adaptation Science Center (SW CASC). SW CASC works to coordinate and collaborate with users and providers of climate information to ensure that the research pursued by CASC-affiliated scientists results in tools, techniques, and actionable information to inform robust decision-making by resource managers, policy makers, and other stakeholders.



SW CASC researchers and their partners are identifying the extent to which temperature, wind speed, solar radiation, and humidity affect regional aridification. They are using both evaporative demand and soil moisture to measure aridification. By improving scientific understanding of the mechanisms of aridification, the team aims to inform water management, irrigated agriculture, and the characterization of drought and wildfire risks.

OBSERVED AND PROJECTED CHANGES IN TEMPERATURE AND ARIDITY

- The southwestern United States is relatively warm and dry. **Temperature in the region is increasing, and will continue to increase in the coming decades.** Average and extreme temperatures are increasing in all seasons. Recent and projected future changes in maximum summer (June, July, and August) and minimum winter (December, January, and February) temperatures are especially large.
- **Aridity (lack of water availability) across the Southwest also is increasing**, although average annual precipitation in the region has changed relatively little over the past 50 years. Annual average precipitation through 2100 is not projected to increase or decrease substantially compared to the observed precipitation of the past 50 years. As temperature increases, however, less precipitation falls as snow, and moisture evaporates more quickly. Over the past hundred years, runoff per unit of precipitation in the upper Colorado River Basin decreased, contributing to a 20% reduction in discharge.
- **Aridity can stress both natural and human systems**, and interacts with other effects of climate change. In California, aridity over the past 50 years was related strongly to duration of the fire season and to area burned, especially in forests during summer.



MEASURES OF ARIDITY

- Two of the many ways of characterizing aridity are **evaporative demand** and **soil moisture**. Evaporative demand, which represents atmospheric aridity, is created by all processes that convert snow, ice, or liquid water near Earth's surface to water vapor. Among these processes are transpiration by plants, evaporation, and the transition of snow and ice directly to water vapor.
- Evaporative demand is difficult to measure in the field across large and diverse areas, but can be modeled with several simplifying assumptions. For example, climate scientists often model **reference evapotranspiration** (evapotranspiration from a large area with uniform vegetation cover and unlimited soil water).
- **Soil moisture** is an ecologically and socially meaningful metric given that it **reflects water balance and affects land use**, the ability of individual species to persist, and interactions among species.
- **Temperature clearly is related to aridity.** However, relations between warming and aridification are not linear, and changes in climate variables other than temperature, such as wind speed, solar radiation, and humidity, also may drive aridification. For example, during summer, more daily variation in reference evapotranspiration in the Southwest is often explained by wind than by temperature.
- Similarly, **soil moisture is not always correlated strongly with changes in precipitation.** In fact, in some parts of the interior United States, seasonal precipitation is increasing while soil moisture is decreasing.



SCIENCE IN PROGRESS

- SW CASC researchers and their partners are identifying the extent to which **temperature, wind speed, solar radiation, and humidity** affect regional aridification, as measured by both evaporative demand and soil moisture.
- A focus on evaporative demand and soil moisture corresponds to a focus on **interactions between moisture demand and moisture supply**.
- Researchers aim to understand whether **drivers of aridification**, and the relations between evaporative demand and soil moisture, **vary across the Southwest and over time**. They are analyzing observations from about 1950 to present, and projections to 2100. The data allow for examination of observed and predicted aridity at a spatial resolution of about 30 km (19 miles), which is applicable to regional and watershed-level phenomena.



PRACTICAL RELEVANCE AND OUTCOMES

- Because **aridification reflects water demand and supply**, understanding the mechanisms of evaporative demand and soil moisture is highly relevant to planning for short- and long-term climate change by diverse sectors, from water management to irrigated agriculture to winter recreation.
- Organisms respond to many more climate variables than temperature and precipitation, and the **ecological effects of changes in different drivers of aridification vary**. For example, the ability of butterflies to find mates and food is highly sensitive to solar radiation, whereas wind speed can strongly affect expansion and intensity of wildfires.
- SW CASC researchers and their partners are contributing to emerging science on attribution of climate extremes, such as extended droughts, and climate-related risks, such as wildfires. **Attribution refers to statistical characterization of the strength of association between an event and potential mechanisms**. For example, current attribution studies can account for the extent to which climate change affected the likelihood or magnitude of a given hurricane or drought.

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