Stanford Woods Institute for the Environment

Research Brief

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California Drought and Climate Change Linked – but Rain Isn't the Only Factor

Higher temperatures intensify effects of decreased precipitation; impact of faster snowmelt, reduced runoff and drier soils associated with "hot droughts" can be severe

Background

California is currently in the midst of a record-setting drought. The ongoing drought event—which began in 2012—includes the lowest precipitation for any calendar year or 12-month period, the highest annual temperature, and the most extreme drought indicators in more than 100 years of record. The extremely warm and dry conditions have led to water shortages, groundwater overdraft, critically low stream flow, very low mountain snowpack and enhanced wildfire risk.

About the Authors

This brief summarizes new findings regarding the risk of drought in California from researchers in Stanford's School of Earth, Energy and Environmental Sciences, and the Stanford Woods Institute for the Environment. The research was led by Woods Senior Fellow Noah Diffenbaugh (Associate Professor, Environmental Earth System Science) in collaboration with co-authors Daniel Swain and Danielle Touma (graduate students in the Department of Environmental Earth System Science).

The drought has spurred a flurry of activity at the state and federal levels with lawmakers proposing and implementing policies and measures to provide near-term solutions to address the current water shortages while weighing the needs of a diverse range of water users including cities and towns, the agricultural sector and the environment. California's March 2014 drought legislation provided immediate relief for those most severely impacted by the drought, but also placed a strong focus on conservation, water efficiency and recycling of water to help restore groundwater reservoirs. The severe drought conditions additionally led to Proposition 1, a water bond bill strongly backed by Governor Brown, and to the Sustainable Groundwater Management Act.

At the federal level, multiple bills have been introduced and efforts are ongoing to find compromise between drought emergency relief legislation sponsored by Senator Feinstein and colleagues in the House. President Obama launched the National Drought Resilience Partnership

as an effort to better coordinate among federal agencies that have jurisdiction over water and land management to improve the government's ability to respond to drought and help communities in need.

While attention has been focused on alleviating the current crisis situation, the question of whether or not climate change can be linked to the severity, duration, or frequency of droughts[1] in California has been much discussed. New research from Stanford earth scientists Noah Diffenbaugh, Daniel Swain and Danielle Touma seeks to provide insights into the drought-climate linkage questions by examining the influence of temperature in contributing to the severity and/or likelihood of drought – an issue that until recently has received less attention than the causes of precipitation deficits.

Key Research Findings – Drought and Temperature Link

- California has historically been more likely to experience drought if low precipitation and warm conditions occur at the same time. These co-occurrences have increased in recent decades, leading to an increase in the percentage of low precipitation years that are also drought years.
- By around 2040, California's climate will have transitioned to one in which there is nearly a 100% likelihood that low precipitation years will also be severely warm.[2]

Although precipitation deficits are a prerequisite for the moisture deficits that constitute drought, high temperatures can greatly increase snowmelt, evaporation from soil, and water use by plants, leading to decreased water availability in streams and in the ground. The impacts of decreased river runoff and soil moisture deficits associated with warm temperatures can be severe,

1 For the purposes of this paper, drought is defined as periods in which the National Oceanic and Atmospheric Administration's drought indicators exceed one standard deviation of their historical variability (which corresponds to about 1/6 years over the course of the 120 year historical record).

2 Experiencing annual temperatures that exceed the historical one-standard-deviation event year-after-year

including enhanced wildfire risk, land subsidence and other associated problems from excessive groundwater withdrawals, decreased hydropower production, and damage to sensitive environmental areas.

Key Research Findings –Temperature and Climate Change Link

- Human-caused warming is increasing the probability of low precipitation and warm conditions occurring at the same time.

Analyzing historical drought metrics, the researchers show that low precipitation and warm conditions have occurred together—and led to drought—more often in the past two decades than in the preceding century. These increases in drought risk have occurred despite a lack of substantial change in the frequency of low precipitation years, because the likelihood of a warm year has nearly doubled. Only those climate model simulations which take into account human influences upon the climate—like the emission of greenhouse gases into the atmosphere—reproduce the observed increase in warm and dry years occurring together.

Key Points for Policymakers

As policymakers at all levels of government seek short- and long-term solutions to drought, the findings by Diffenbaugh, Swain and Touma raise a few key points to consider about the links between temperature, precipitation and climate change in California:

- Even without changes in precipitation, soil moisture deficits are exacerbated by unusually warm conditions;
- The increasing occurrence of "hot droughts" has significant implications for Sierra Nevada snowpack and the many human and natural systems that depend on snowpack;
- The warming that has already occurred in California means that decision-makers can expect to face conditions like the current drought more frequently than in the past;
- Increasing risk of consecutive warm-dry years raises the possibility of more frequent extended drought periods such as the current drought event;
- Peaks in California's snowmelt and surface runoff are likely to continue to be more pronounced and to occur earlier in the calendar year;
- Past gains in urban and agricultural water use efficiency mean that short-term water conservation in response to water shortages will become increasingly challenging.

Conclusions

The Diffenbaugh team's results highlight the fact that efforts to understand drought without examining the role of temperature miss a critical contributor to drought risk. Their results show that even without changes in probability of extremely low precipitation years, the risk of severe drought in California has already increased due to persistently warm conditions induced by human-caused global warming. There is therefore strong evidence that climate change is already having an impact on California by increasing the likelihood of conditions that have historically led to severe drought. In addition, continued global warming is likely to cause a transition to a situation in which every low precipitation period will coincide with temperatures well above those that occurred during the 20th century.

This Research Brief is based on findings from the study *Anthropogenic warming has increased drought risk in California*, (March 2015, PNAS).

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