A 'no snow' California could come sooner than you think

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It was 55 degrees and sunny Thursday at Sugar Bowl Resort, where the opening day of the 2021 ski season—already delayed because of warm weather—was still listed as "TBD."

"Winter hasn't quite arrived in Tahoe yet," officials wrote in a note about

the postponement. "The team will be working nightly and ready to flip the switch when Mother Nature cooperates."

But the mountain isn't the only place feeling the pinch from lack of snow. A new study led by researchers at the Lawrence Berkeley National Laboratory found that dwindling snowpack across California and the western United States could shrink dramatically more—or in some cases disappear—before the end of the century.

The study, published recently in the journal *Nature Reviews Earth and Environment*, paints a worrisome picture of the "potentially catastrophic consequences" of a future with less snow, including the massive implications it holds for California's water supply, as well as rippling effects on soil, plants, wildlife and even the increased frequency of wildfire.

Should greenhouse gas emissions continue unabated, the study found, winters of low snow, or even no snow, could become a regular occurrence in as little as 35 years.

The projections "are a little bit shocking," said Alan Rhoades, a hydroclimate research scientist and co-author of the study. "As a kid who grew up in the Sierra, it's kind of hard to fathom a low- to no-snow future."

In many ways, the changes have already begun. California this year experienced its hottest summer on record, while Los Angeles and San Diego both just saw their driest Novembers in decades. The entire state is also under a drought emergency.

But the paper is the first to synthesize "any and every available study" of future snowpack projections to construct a more confident timeline, said Erica Siirila-Woodburn, a research scientist at the Berkeley Lab and

another co-author of the study.

Many of the worst effects will be felt in California, she said, where snowpack in the Sierra Nevada and Cascade ranges could decline 45% by 2050, compared with about 25% in other western ranges such as the Rockies and the Wasatch-Uinta.

Jeffrey Mount, a water scientist at the Public Policy Institute of California who did not work on the study, said that level of snow loss could fundamentally alter life in the Golden State, where mountains have historically served as a critical resource for regional water supplies by capturing, storing and releasing moisture downstream.

"Believe me, we all read it," Mount said of the study, noting that California has "built an entire water supply system around the reliable appearance of snowpack in our mountains."

Crucially, he said, the steady, slow melting of snow each spring and summer has long acted like a time-release that provides more water at a moment when precipitation tends to stop and demand begins to surge.

Snowpack on April 1, when it is typically its deepest, was only 60% of its average this year, according to the California Department of Water Resources.

"If the snow is not going to melt off in the spring like it used to, we've got some major challenges for how we operate our reservoirs," Mount said, "because it's all built around them. Everything's built around them."

But snow loss won't affect only water supplies. The researchers described a "cascade of implications" that could shift the state's soil, plants and wildlife and also negatively affect forest productivity and ecological health. It could also increase the risk for flash floods and

debris flows, as well as the prevalence and severity of wildfires, they said.

"It's hard to disentangle this really interconnected system, in terms of all these different places where water hooks to different parts of the environment," Siirila-Woodburn said. "It's really this holistic system that we have to think about jointly."

The researchers defined "low snow" as when the snowpack (or snow water equivalent) falls below the 30th percentile of the historical peak. "No snow" is when that number falls below the 10th percentile.

California has already seen bouts of both, such as when snowpack in the Sierra dropped to an unprecedented 5% of normal in 2015. But the state could start to experience "episodic periods"—or five consecutive years—of low to no snow as soon as the late 2040s, researchers said.

Persistent periods, or 10 consecutive years, of low-to-no snow could arrive in California by the 2060s. In other parts of the western U.S., persistent periods don't emerge until the 2070s.

"We can maybe manage around two years, three years of low- to no-snow," Rhoades said, "but when you start to get five years ... or that persistent 10 years, I think that starts to undermine some of the historical management strategies that have been used."

The reasons for snow loss are myriad, but most are tied to climate change. Warming temperatures mean more precipitation is falling as rain instead of snow—and rain has less water storage potential than its colder counterpart, Rhoades said.

What's more, many of the storms that do bring moisture to California come across the warm Pacific, while other ranges such as the Rockies

get colder storms that move in from the northern Arctic. And with a lower average elevation than some other western ranges, the Sierra also have a harder time maintaining snow levels.

The researchers hoped their findings could be a "call to action" that will spur residents, policymakers and innovators to elevate snow loss to the level of other climate hazards like sea level rise and wildfires, which tend to make more headlines, they said.

"This isn't some hypothetical make-believe future," Siirila-Woodburn said, noting that snowpack in the region has already decreased by about 20% since 1950—the equivalent of the storage capacity of Lake Mead, the nation's largest reservoir. "This is something that's already happening now."

One high-emission climate model used in the study found that as few as 8% of the years between 1950 and 2000 would be classified as having low to no snow in the western United States. Between 2050 and 2099, that number could soar as high as 94%.

But there are solutions, including water conservation, infrastructure investments, desalination and, crucially, reducing greenhouse gas emissions, the researchers said. Aggressive forest management will also play a key role because less dense forests allow for deeper snowpack.

John Andrew, deputy director of climate resilience at the California Department of Water Resource, said via email that it will require an "all of the above" approach to slow the trend.

"With a state as diverse as California, there is simply no 'one-size-fits-all' solution—it will take a portfolio of diverse strategies, implemented primarily at the regional level," Andrew said.

"That said, there is obviously a high priority currently on responding to the drought, with a particular emphasis on assisting small, rural communities that do not have access to safe and affordable drinking water," he added.

Also of critical importance are adaptation strategies, including techniques to store excess surface water underground for later use, the researchers said.

Forecast-informed reservoir operations, which use weather and water forecasts to inform decisions about retaining or releasing water from reservoirs, also show promising signs of increasing water storage in California.

Yet there is still much to be done. In September, Gov. Gavin Newsom allocated more than $5 billion of his $15-billion climate package toward drought response and water resilience—but in the same month, Californians backslid in their efforts to conserve water.

"Decreasing snowpack is one of several challenges facing California water managers, including aging infrastructure and declining ecosystem health," Andrew said, adding that "water conservation should be a way of life in California."

Still, the researchers said they hoped their study would inspire less "doom and gloom" and more discussion of solutions—particularly since their findings were primarily based on a high-emission scenario that is not yet inevitable.

Water managers and policymakers have already reached out about incorporating the study's findings into their work, they said.

But though budgets, infrastructure, legislation and conservation can all

be improved upon, the necessary conditions for that Sierra snow Rhoades played in as a kid are admittedly harder to come by in a warming world.

Unfortunately, he said, "the freezing point of water is non-negotiable."