A Body of Work on Fire

Above: *wildfire in Stanislaus National Forest, California, 2013. U.S. Forest Service photo by Mike McMillan.*

California's wildfire season this year made headlines throughout late summer, with front-line firefighters reporting that local agencies were overwhelmed by the pace and severity of the blazes. Said one deputy chief, "Normally during the fire season, Cal Fire will respond to about 300 individual fires per week. This year, in just one week, the agency responded to 1,000 fires." By mid-September, a total of 6,324 fires had burned a cumulative area of 1,493,506 acres, according to the California Department of Forestry and Fire Protection and the National Interagency Fire Center. Fifteen people were killed, including eight civilians and six firefighters.

Lamont bioclimatologist Park Williams was saddened but not surprised. His research has focused on the correlation between intensifying hot and dry spells and the rapidly rising increase in forest fire risk.

"It makes sense that this year was a really big fire year, because it was a record-breaking hot summer. And what we see with fire statistics is that heat is really the single most important climate variable to fire."

Above: *this 2016 Montana fire devoured more than 8,000 acres of forest, along with more than 60 homes and outbuildings. Photo by Mike Daniels.*

"It makes sense that this year was a really big fire year, because it was a record-breaking hot summer. And what we see with fire statistics is that heat is really the single most important climate variable to fire," said Williams. A 2016 study that he and a colleague published in the Proceedings of the National Academy of Sciences showed that human-induced climate change has doubled the area affected by forest fires in the U.S. west over the last 40 years. According to the study, between 1984 and 2015 heightened temperatures and resulting aridity caused fires to spread across an additional 16,000 square miles than would otherwise have been consumed – an area larger than the states of Massachusetts and Connecticut combined. The authors warned that further warming will increase substantially the frequency and severity of wildfires in coming decades.

"If it weren't for the warming trend, we would've had about half as much forest fire over the last 40 years," said Williams. He cautioned against reading this as a simple equation. The growing fires in the western U.S. are also a product of a century of forest management. Fire, as dangerous and chaotic as it can be, has traditionally been a natural ecological process, typically started by lightning. Historical fires tended to be low burning and mild by comparison to the rapidly spreading crown fires common today.

"There are many natural ecological processes that depend on fire, and over the last century, as we've removed fire from the western U.S., forests have been out of whack. So not only are our ecosystems forced to function in an unnatural way because of the exclusion of fire, now when fires occur there is that much more fuel to intensify and spread the flames," explained Williams.

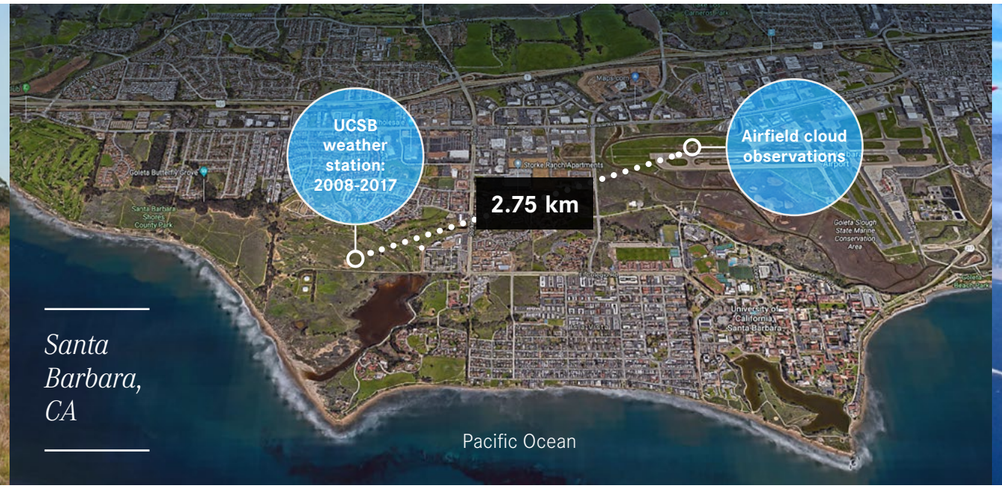
1910 was a turning point in American forest management history. It was a very dry year, and the usual number of forest fires had multiplied. Forest management officials saw this as a reason to change their approach and to dedicate their resources to putting out forest fires. Throughout the decades since then, firefighting improved, in effect short-circuiting the natural fire process.

"We kept getting better and better at fighting fire right through the 1980s. Back then the experts didn't anticipate this huge blow-up of fires. Firefighters thought that fires would stay small because they were really good at fighting them. They used to think fires that burned more than 100 acres were really big fires. And now such small fires are minor. Now we have fires that consume 100 acres per second."

According to Williams' research, the trajectory promises to worsen as the Earth continues to warm, drying the overabundance of vegetation and priming western North America for massive fires.

His most recently published research – which identified a clear relationship between fire occurrence and the reduction of cloud cover over coastal California – is the result of more than a decade of investigations of wildfires and fieldwork that dates back to Williams' years as a graduate student in California.

"It is really tough to imagine how things will look after another couple of decades of warming. We are seeing a reemergence of fire after a century of exclusion. That is not all bad. It's a different type of fire from the naturally occurring ecological process, however. Now we have people living in these areas, and fire is dangerous. Towns built into forests are increasingly at risk. And we're going to see some towns unavoidably burning down. Those towns should be prepared,"



Above: *weather station operated by the University of California, Santa Barbara. Photo by Park Williams. Aerial view of Santa Barbara, from Google Maps.*

Then, while at the University of California, Santa Barbara, he and his colleagues studied the importance of clouds for forests. The main tool for his fieldwork was a single weather station that Williams helped build in 2007. This weather station has since been collecting very accurate measurements of radiation.

"It's been recording the amount of sunlight and also the amount of radiation that the ground reflects back upwards. And it's been logging the amount of longwave thermal heat that comes down from clouds and up through the ground. This type of very careful sets of radiation measurements is actually very rare, and we now have a 10-year record of these measurements made every 10 or 15 minutes."

That weather station is adjacent to Santa Barbara Municipal Airport. Williams was able to use those radiation measurements along with the tens of thousands of coincident cloud measurements made routinely from the airport. From this analysis, he and his colleagues quantified the relationship between clouds and the radiation or energy balance near Earth's surface.

"That's how we were able to determine that if you lose, say, 30 % of clouds at 10 am there is a specific amount of watts per square meter of extra sunlight."

This 2018 study linked increasing summer temperatures brought on by a combination of intensifying urbanization and warming climate to the dissipation of once common low-lying morning clouds in many southern coastal areas of the state, and in turn to the increased risk of wildfires. As clouds decrease, the rate of larger, more intense fires escalates.

Urban pavement and infrastructure do not cool off as quickly as the surrounding countryside, resulting in warmer nights and mornings, and reduced evaporation from wet soils and vegetation often results in warmer days. This so-called heat-island effect makes cities generally hotter than rural areas. At the same time, overall temperatures have been rising in California because of global warming, and this warming has boosted the effect. In the 2018 study, Williams and his colleagues found a 25 to 50 percent decrease in low-lying summer clouds since the 1970s in the greater Los Angeles area.

"areas where clouds have decreased, the fires should become more intense and more difficult to contain"

Left: *low-level clouds over Los Angeles (seen in early afternoon) and other urban areas of coastal southern California are becoming rarer, leading to increased fire risk. Photo by Park Williams.*

Williams' team also discovered that periods of less cloud cover during the summer are correlated with lower vegetation moisture, and thus a greater danger of fire.

However, the study did not find that the total area burned each summer has increased as a result of decreases in cloud shading. There are too many other factors at play, said Williams. These include yearly variations in rainfall, winds, locations where fires start, and, most importantly, decreases in burnable area as urban areas have expanded and steady increases in the effectiveness of firefighting.

"But the dice are now loaded, and in areas where clouds have decreased, the fires should become more intense and more difficult to contain. At some point, we'll see if people can continue to keep up."

Williams says this year's record-breaking wildfires in inland California are not a consequence of the dissipation of clouds over the coastal area of the state. Instead, they are the result of a combination of factors, including global warming and its drying impact; multiple decades of decreasing precipitation due to natural variability in the atmospheric circulation pattern over the Pacific Ocean region; the increasing number of people, the sources of most fires in California; and dense vegetation that has been aided by a century of firefighting.

Williams is now in the process of researching the history of drought in North America. Specifically, he is examining thousands of tree-ring records to study the infamous megadroughts that occurred in the western United States and Mexico during the Medieval period approximately 800–1200 years ago. Relating those tree-ring records to more recent climate records, Williams finds that after a relatively wet 400 years, the western United States is currently 19 years into a drought that so far is on pace to rival the worst megadroughts of the past 1200 years.

Above: *Lamont Associate Research Professor Park Williams. Lamont photo.*