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A Drier Future Sets the Stage for More Wildfires

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Follow the Freshwater: By predicting droughts and floods and
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November 8, 2018 was a dry day in Butte County,
California. The state was in its sixth consecutive year of
drought, and the county had not had a rainfall event
producing more than a half inch of rain for seven months.
The dry summer had parched the spring vegetation, and
the strong northeasterly winds of autumn were gusting at
35 miles per hour and rising, creating red flag conditions:
Any planned or unplanned fires could quickly get out of
control.

Sure enough, just before daybreak, strong winds whipped
a stray spark from a power line into an inferno. The Camp
Fire became the most destructive fire in California's
history, scorching approximately 240 square miles,
destroying nearly 14,000 buildings, causing billions of

dollars in damage and killing 88 people. Later the same day, the Woolsey Fire broke out in Los Angeles County, burning 150 square miles and killing three.

Droughts can create ideal conditions for wildfires. Lack of rain and low humidity dry out trees and vegetation, providing fuel. In these conditions, a spark from lightning, electrical failures, human error or planned fires can quickly get out of control.

Global climate change (https://climate.nasa.gov/effects/) is predicted to change precipitation and evaporation patterns around the world, leading to wetter climate in some areas and drier in others. Areas that face increasingly severe droughts will also be at risk for more and larger fires. Several NASA missions collect valuable data to help scientists and emergency responders monitor droughts and fires. Some instruments monitor water in and below the soil, helping to assess whether areas are moving toward dangerous droughts. Others watch for heat and smoke from fires, supporting both research and active disaster recovery.

Understanding how fires behave in dry conditions can help firefighters, first responders and others prepare for a hotter, drier future.

Climate Change: Not Just Wet

Earth's warming climate is forecasted to make global precipitation patterns more extreme (https://svs.gsfc.nasa.gov/11281): Wet areas will become wetter, and dry areas will become drier. Areas such as the American Southwest could see both reduced rainfall and increased soil moisture evaporation due to more intense heat, and in some cases, the resulting droughts could be more intense than any drought of the past millennium.

Ben Cook (https://www.ldeo.columbia.edu/user/bc9z) of NASA's Goddard Institute for Space Studies (https://www.giss.nasa.gov/) (GISS) in New York City researches "megadroughts (https://www.nasa.gov/press/2015/february/nasa-study-finds-carbon-emissions-could-dramatically-increase-risk-of-us)" — droughts lasting more than three decades. Megadroughts have occurred in the past, like the decades-long North American droughts between 1100 and 1300, and the team used tree ring records to compare these droughts with future projections. He and his team examined soil moisture data sets and drought severity indices from 17 different future climate models, and they all predicted that if greenhouse gas emissions

continue to increase at their present rate, the risk of a megadrought in the American Southwest could hit 80 percent by the end of the century. Additionally, these droughts will likely be even more severe than those seen in the last millennium.

Such severe droughts will affect the amount and dryness of fuel such as trees and grass, Cook said.

A Drier Future Sets the Stage fo…

Droughts can create ideal conditions for wildfires. Dry trees and vegetation provide fuel. Low soil and air moisture make it easier for fires to spread quickly. In these conditions, a spark from lightning, electrical failures, human error or planned fires can quickly get out of control. As Earth's climate warms and precipitation patterns change, increasingly severe droughts will leave some areas of the world vulnerable to increasingly severe fires.
Credits: NASA/ LK Ward
This video can be downloaded for free at NASA"s Scientific VIsualization Studio. (https://svs.gsfc.nasa.gov/13253)

"Fire depends on two things: having enough fuel and drying that fuel out so it can catch fire. So in the short term, more droughts probably mean more fire as the vegetation dries out," said Cook. "If those droughts continue for a long period, like a megadrought, however, it can actually mean less fire, because the vegetation will not grow back as vigorously, and you may run out of fuel to burn. It's definitely complicated."

Current and future NASA measurements of soil moisture and precipitation will help to evaluate climate models' predictions, making them even more accurate and useful for understanding Earth's changing climate.

Cook and his GISS colleague Kate Marvel (http://www.marvelclimate.com/) were the first to provide evidence (https://www.nasa.gov/feature/goddard/2019/nasa-study-human-influence-on-global-droughts-goes-back-100-years) that human-generated greenhouse gas emissions were influencing observed drought patterns as long ago as the early 1900's. By showing that human activities

have already affected drought in the past, their research provides evidence that climate change from human-generated greenhouse gas emissions will likely influence drought in the future.

Staying Ahead of the Fire

If the future does hold megadroughts for the southwestern United States, what might this mean for its fire seasons?

"Once we change the climatology and get drier and drier fuels, we should expect more intense fires and higher fire severity," said Adam Kochanski (https://www.atmos.utah.edu/people/all-faculty/adam-kochanski.php), an atmospheric scientist at the University of Utah, referring to the size and impact of the fires. If fuels are moist, the fire is more likely to stay close to the ground and be less destructive, he said. Dry trees and plants make it more likely that flames will reach the forest canopy, making the fire more destructive and harder to control.

Kochanski and Jan Mandel (https://clas.ucdenver.edu/mathematical-and-statistical-sciences/jan-mandel) of the University of Colorado Denver used data from NASA and other sources to simulate the interactions between wildfires, soil moisture and local weather. They built on previous work by the National Center for Atmospheric Research (https://ncar.ucar.edu/) (NCAR) and others to develop the SFIRE module for the widely used Weather Research and Forecasting model (https://www.mmm.ucar.edu/weather-research-and-forecasting-model) (WRF).

This module uses data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS (https://terra.nasa.gov/about/terra-instruments/modis)) aboard its Aqua and Terra satellites, and the Visible Infrared Imaging Radiometer Suite (VIIRS (https://disasters.nasa.gov/instruments/viirs)) aboard the Suomi National Polar-Orbiting Partnership (Suomi NPP) spacecraft.

Weather influences fires, but fires also influence local weather by producing heat, water vapor and smoke, Kochanski said. The winds from large fires can alter local weather patterns, and in extreme conditions, generate firestorms and fire tornadoes.

"It's not uncommon for people involved in wildland fires to report that although the wind is not very strong, the fires propagate very fast," Kochanski said. "If it isn't that

windy, but your fire is intense and releases a lot of heat, it has the potential to generate its own winds. Even if the ambient winds are weak, this fire will start moving as if it were really windy."

Better modeling of these interactions not only helps firefighters better predict where and how a wildfire might spread, but also helps forest managers know whether a planned burn is safe.

A Tale of Fire and Snow

Fires' effects persist long after they are extinguished, and the availability or lack of fresh water plays an important role in vegetation regrowth and recovery. Dry conditions may prevent new seeds from germinating in the burned areas. Vegetation loss can lead to erosion and sediment blocking waterways, and firefighting chemicals may contaminate water sources.

Forest fires can have impacts on future winter snowpacks as well, said Kelly Gleason (https://www.pdx.edu/esm/dr-kelly-gleason), a snow hydrologist and assistant professor at Portland State University. "Snowpack" refers to the snow that accumulates over an entire winter, rather than a single snowfall.

Here too, NASA data are key to understanding the processes involved. Gleason and her team used 16 years of data from NASA's MODIS instrument to investigate wildfires' effects on snow melt in forests in the American West. They discovered that soot and debris from fire makes snow darker and less reflective for up to 15 years after a fire.

"It's like wearing a black T-shirt on a sunny day," Gleason said. "It primes the snowpack to absorb more sunlight energy. And there's more energy anyway, because the forest canopy was burned, so more sun comes through."

Their survey of roughly 850 fires between 2000 and 2016 showed that snow in burned forests melted, on average, five days earlier than snow in unburned forests. In some areas the snow melted weeks or months earlier than normal, Gleason said.

"Every year we experience earlier snow melt, there are strong relationships with big, hot, long-lasting fires the following summer," she said. "It creates this vicious cycle where snow melts earlier due to climate change, which extends the summer drought period where the soil dries

out, and when the fuels dry out, you get these big fires. This further accelerates snowmelt, further extending the summer drought period and fire potential."

Modeling a safer future

Mandel and Kochanski's fire-atmosphere model is already in operational use in Israel and Greece. While the software requires computing expertise to use, it is available for free (https://www.openwfm.org/wiki/How_to_get_WRF-SFIRE), consistent with NASA's mission to freely provide its data and other products to the public.

Branko Kosović (https://staff.ucar.edu/users/branko), program manager for Renewable Energy for the Research Applications Laboratory and director of the Weather Systems and Assessment Program at NCAR, also used WRF to develop the fire prediction system for the state of Colorado's Division of Fire Prevention and Control. This model uses a related module called FIRE and produces a fire, weather and smoke forecast useful for both wildfires and planned fires.

Kosović is also using the WRF system for his research, which uses NASA remote sensing data and machine learning to estimate fuel moisture daily over the contiguous Unites States.

"Measuring live fuel moisture [currently] has to be done manually," Kosović said. "People have to go out, take the live fuel, and essentially cure it in ovens to see how much moisture there is. It's very labor intensive. And you can imagine that, because of that, the data is sparse, both in space and in frequency and time."

Kosović, Mandel and Kochanski hope to build systems that will give forest managers better information to plan controlled fires and help improve resource allocation during wildfires, leading to better risk assessment and recovery.

NASA scientists monitor both freshwater (https://www.nasa.gov/feature/goddard/2019/nasa-investigates-our-changing-water-world) and fires (https://www.nasa.gov/feature/goddard/2018/nasa-covers-wildfires-from-many-sources) constantly, from space, the air and the ground, collecting short- and long-term data as Earth's climate continues to change. Programs such as the NASA Earth Science Disasters Program (https://disasters.nasa.gov/fires) use satellite data to track active fires, monitor their effects on air

quality and perform research that helps communities be more prepared before disasters strike. And looking to the future, modeling (https://www.nasa.gov/feature/goddard/2019/managing-freshwater-across-the-united-states) plays a key role in preparing for changing drought and fire seasons around the world.


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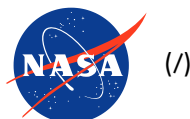
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