Lab develops unprecedented long-term wildfire prediction model

October 7 2020, by John Spizzirri

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Wildfire indices and high-resolution climate models combine to produce a detailed historical analysis of wildfire events across the U.S. and suggest the potential for more severe and frequent fires in the latter half of the century.

The list is long, some of the names familiar: Sunflower, Paradise, Whitewater-Baldy, Apple, Pinecreek. Names that invoke images of pastoral respites away from the busy world.

Now those names are synonymous with wildfires.

The number and severity of wildfires are making headlines across the globe, from the Western United States to Brazil, from Siberia to Australia. Wildfires devastate the environment, decimating huge swaths of land and wildlife populations—it is estimated, for example, that a half billion animals perished in the megafires that recently swept Australia. Beyond their impact on nature, wildfires also take a toll on air quality, infrastructure, homes and human lives.

Combining data from well-established fire indices and historical climate records, scientists with the U.S. Department of Energy's (DOE) Argonne National Laboratory are mapping out a forecast for wildfire events across the contiguous United States and Alaska that spans the rest of the century. They also are applying that forecast to predict how wildfires might affect essential infrastructure, particularly the nation's electric grid.

Understanding their location, frequency and severity could help infrastructure operators, land management agencies and local governments develop plans to mitigate the devastation wrought by future wildfires.

Fanning the flames of interest

In 2007, Yan Feng was a postdoctoral researcher at the University of California at San Diego, when she witnessed her first wildfire, an event severe enough to close the school for several days.

"People were wearing masks because the air quality was so bad, you could see the ashes floating everywhere," recalled Feng, now a principal atmospheric and climate scientist in Argonne's Environmental Sciences (EVS) division. "But it was such an impressive event that I became interested in wildfires."

She joined the lab in 2010, sidelining that interest for a few years until a research institute sought Argonne's expertise and supercomputing resources to develop a high-resolution climate model and fire hazard map of the Western United States.

Feng's work on that project sparked her interest in wildfires again, and she began writing funding proposals to continue research on the topic. Soon she would discover that others at Argonne shared in her pursuits.

One of those was Mark Petri, director of Argonne's electric power grid program, whose work includes analysis of critical infrastructure resilience. One of the ways to test that resilience is to identify and understand external hazards, like extreme weather, that can affect the grid and other essential infrastructure.

As it turns out, Argonne already had built a fairly sizeable knowledge base of those hazards, save one in particular.

"We do well with hurricanes and ice storms, derechos and nor'easters," said Petri, "but the one area in which we seemed to be lacking was wildfires."

And what they wanted, more specifically, were data that focused on how changes in climate impact wildfires.

Reenter Feng.

Working through Argonne Laboratory Directed Research and Development (LDRD) funding garnered by Petri, she and colleagues Jiali Wang and Emily Brown published a paper in the journal *Environmental Research Letters* that examines wildfire trends over the past 30 years. Using the well-known Keetch-Byram Drought Index (KBDI) and exceptionally high-resolution climate observations from sites across the country, they illustrated how those trends could affect future events.

The KBDI gages the amount of moisture available to local vegetation in upper soil layers and the decomposing organic material matrix, or deep duff, that rests above those layers. An index point of zero suggests that the ground is well saturated; at 800, drought conditions prevail.

While others have conducted historic wildfire trend analyses using the KBDI before, the Argonne researchers were the first to obtain one at unprecedented resolution and over such a large area and time period.

If you think of a grid, most grid points used in current studies account for an area, or spatial resolution, in the range of 10 to 50 km. Feng's team used observations that encompassed areas of just 4 km over the contiguous United States, for the period 1982 to 2017.

But because the KBDI and other fire indices mainly serve as predictive indicators of wildfires, they had to find some way to relate the index to actual fires, which they did by finding historical data for fires that occurred during that period.

"So, we did this correlation analysis and found significant correlations between the fire index and the observed burning area from wildfires over the last 36 years," said Feng. "That gave us confidence for using this predictive index for future estimates."

The index was then applied to regional climate models produced by Jiali Wang and Environmental Sciences colleague Rao Kotamarthi using a Weather Research and Forecast (WRF) model at a grid spacing of 12 km. Taking a business-as-usual approach that considered uncertainties from different input data sources, they were able to predict the frequency and severity of future wildfires from the mid-to-late 21st century over both the contiguous United States and Alaska.

It's more complicated

In comparison to other climate-induced phenomena, like more intense hurricanes or more frequent and extreme storms, wildfires are more complicated.

In addition to regional weather conditions, researchers must consider other key environmental factors that can promote and spread a fire. There is topography—basically, the lay of the land—and land management; a slope that is wind-facing causes a fire to spread more quickly, and a surface loaded with dry wood, leaves and bushes literally adds fuel to the fire.

Different indices consider just some of these variables, and each has its pros and cons, noted Wang, an Argonne atmospheric and earth scientist and coauthor of the paper. The KBDI, for example, focuses on temperature and precipitation, but doesn't account for wind which, as we've seen, is critical for fire spread.

"We started with a fairly simple fire index that gives you the risk, but can't predict the fire as accurately as the weather forecast," Wang said. "It's pretty good over regions that have rich fuel, but for areas that don't have that, we need to look at other indices with fewer limitations and possibly better predictive capabilities."

Despite these limitations, the team was able to use its historic data as a solid baseline for predicting wildfire potential through the latter half of this century. The outlook is worrying, to say the least, driven predominantly by rising temperatures.

Already, extreme temperatures, high winds and drought conditions in the West are providing a grim preview of things to come. As of late September, wildfires had created an enormous swath of destruction from Southern California north through Oregon and Washington, burning a record-breaking 4 million acres in California alone.

"Based on ours and other studies, there is an increase in terms of the frequency and severity of the fires that are occurring in the present compared to two or three decades ago," said Feng.

And according to the research, things are only going to get worse.

"We ran the WRF models many times, and all of the outputs project more numerous, more frequent and more extreme fire events, especially in the West, where there are already many fires," added Wang. The same will hold true for the South and Southeast, already prone to damage from hurricanes and other extreme hazards.

They also found that the potential for extreme fires could extend to parts of the country where wildfires presented little risk in the past, like the Midwest, the Northeast and Alaska.

While typically ignored in such studies owing to lack of observational data and the computational requirements to add it to simulations, Alaska was included in the team's paper, in which they wrote that the state "has warmed twice as fast as the rest of the nation, and is experiencing permafrost temperature rise, which can lead to more wildfires."

The resulting data will be used by the Argonne team to build a fire risk indicator into their infrastructure risk assessment model, one that already addresses those other, more widely studied extreme hazards.

The model serves as a kind of hazard roadmap, providing utility companies and other infrastructure operators with long-range hazard forecasts, whether wildfire or hurricane. Knowing the potential timing and severity of any one of these can help them develop a better management plan for the security of essential infrastructure, particularly the nation's power grid.

This might mean better land management, like cutting back trees and bushes around utilities, or moving power lines where feasible. Work is underway to develop smarter strategies for shutting down power when systems are at risk of overheating, avoiding outages like those for which one of California's largest utilities was criticized during wildfires that swept Northern California, last year.

"The work that the Argonne team has produced will help reinforce the hazard resilience models we are developing to provide well-thought strategies for the safety of the nation's people, land and infrastructures," said Petri. "It will also serve as an asset to others working on wildfire mitigation strategies throughout the lab."

This research was published online as "U.S. wildfire potential: a historical view and future projection using high-resolution climate data" in *Environmental Research Letters*, July 22, 2020.

More information: Emily K. Brown et al. U.S. wildfire potential: a historical view and future projection using high-resolution climate data, *Environmental Research Letters* (2020). DOI: 10.1088/1748-9326/aba868

Provided by Argonne National Laboratory