Keri Allan

WIL

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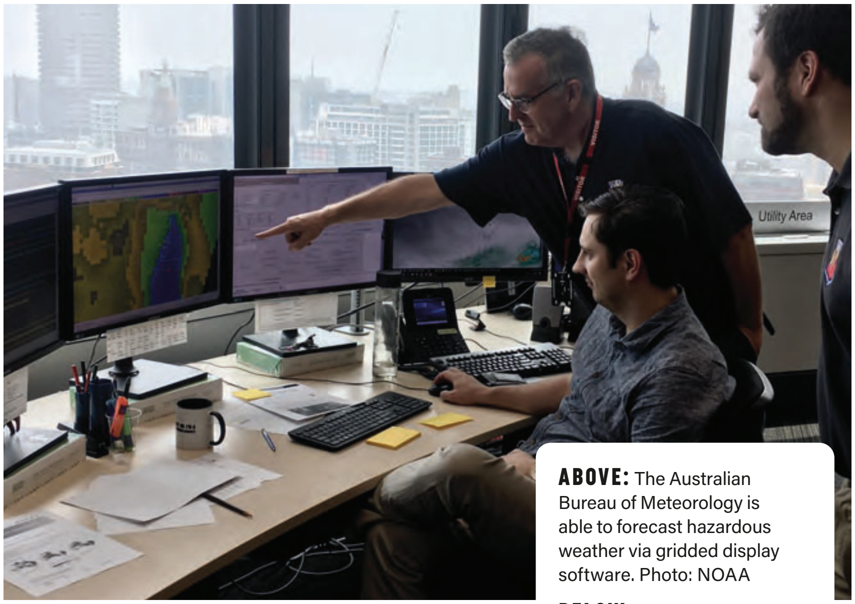
According to scientists, the scale of the 2020 Australian bushfires was way beyond anything climate science predicted. What is being done to improve wildfire forecasting and lessen the impact on the environment?

Wildfires have burned around the world this year, from Australia to California. These forest and wildland blazes are part of nature, but climate change is making them more frequent and intense. Although many wildfires are caused by humans, weather plays a major role in how easily a fire might start, how fast and in what direction it spreads, and how dangerous it becomes.

Wildfire forecasting is different from general weather forecasting in that it requires a unique set of skills and knowledge. As with any specialty forecasting, it's imperative to understand how various meteorological variables affect the end user – in this case firefighters – and the environment in which they're applying that forecast data.



ABOVE: The Australian Bureau of Meteorology is able to forecast hazardous weather via gridded display software. Photo: NOAA

BELOW: The fire on Mount Solitary in New South Wales highlighted the complexity of fire and atmospheric interactions. Photo: BoM

"For fire weather forecasters, the meteorologist has to understand the impacts of terrain on weather, as well as how meteorological factors affect behavior. This is key since firefighters plan their operational decisions on the weather forecast, as that directly impacts the fire behavior forecast," notes Royce L Fontenot, senior service hydrologist and incident meteorologist at the US NOAA.

"At NOAA, forecasters complete basic training in fire weather and behavior before they are allowed to issue fire weather forecasts. Since 1928 the National Weather Service [NWS] has also supported a cadre of incident meteorologists [IMET] who are specifically trained to support wildland fire incidents by providing on-site weather forecasts. IMETs receive more advanced training in fire behavior and fire meteorology and must then train on actual large wildland fires with a more experienced IMET for at least 20 days."

Wildfire prediction can be broken down into two key questions: what's the fire potential on any given day at a given location or region and, once a fire has ignited, where will it burn and what behavior will it exhibit? The answer to the first question involves fuel loads and structure, assets under threat, and seasonal and local dryness. The second relates to day-to-day synoptic weather patterns and how they drive behavior and spread.

"A challenge in fire prediction and response compared with other meteorological hazards such as thunderstorms or tropical cyclones is the multidisciplinary nature of the hazard," notes Dr Mika Peace, a fire researcher at the Australian Bureau of Meteorology (BoM). "An additional factor is ignition – until there's a fire in the landscape, there's no hazard. In the 2019/2020 fire season Australian meteorologists worked closely with fire behavior analysts to predict the spread of fires. Predictive fire mapping was used across spatial scales of synoptic meteorology down to details of slope, aspect and local wind channeling.

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"The emphasis in fire prediction is on wind-driven surface spread, with current research on developing tools to predict elements of fire behavior such as spotting, plume depth and structure, and topographic enhancement using quantitative measures rather than the ability to provide qualitative descriptions," she adds.

The importance of collaboration

During incidents, meteorologists from agencies around the world come together to support their counterparts. For example, BoM's long-term collaboration with the Japanese Met Agency enabled provision of rapid-scan two-minute data from the Himawari satellite during Australia's latest fire season. A real-time trial of BoM's pyrocumulonimbus prediction tool – the PyroCB Firepower Threshold tool – was conducted and supported by the international pyroCB monitoring effort using multiple satellites.

During the New South Wales fires, the USA provided incident management teams that liaised regularly with BoM meteorologists in the field. "These collaborations provided significant insights into the cross-Pacific differences in fire services and were a really valuable learning opportunity. Post-season, collaborations with US researchers are planned to study the event and document the processes that contributed to the devastating fires," notes Peace.

"There's been a partnership agreement for wildfire assistance between our two countries since 2006, and almost every year since we've assisted each other to combat a number of devastating wildfires," adds Fontenot. "I think one of the key lessons from the 2019/2020 Australian fires is that of interoperability. The firefighting agencies in the USA, Australia, New Zealand, Mexico and Canada all use a similar command structure and qualification system for wildland firefighting. With weather forecasting, the situation is similar for the NWS and BoM. We use the same software solution for the creation of our gridded forecast information – Graphical Forecast Editor (GFE). This enabled the NWS IMETs to integrate rapidly with BoM operational staff."

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Tracking tech and project work

Work continues on developing new technologies and models that will improve fire forecasting and tracking accuracy. Satellites and line scans are two of the main tools for real-time tracking of wildfire front location. The availability and frequency of these technologies has advanced considerably in recent years, BoM's Peace notes. However, they are both still limited under extensive cloud coverage.

"The use of drones is an emerging technology to support mapping of firelines, but has been limited for safety reasons," she says. "The latest technologies include enhanced tools for mapping of fire spread and spatial platforms for providing fire spread predictions. Future plans aim to develop prediction capabilities by using more complex spatial, temporal and dimensional meteorological fields as inputs to fire spread and fire prediction models. The goal is to improve the accuracy of fire perimeter predictions, as well as capture elements of fire behavior relating to fire plume processes and fire-atmosphere interactions.

ABOVE: Incident meteorologists (IMETs) installing a portable Remote Automated Weather Station (RAWS) near Rogue River, Oregon, during the Taylor Creek/Klondike wildfire in August 2018. Photo: NOAA

LEFT: Drone technology is expected to play a significant role in future fireline mapping

"A major project is underway in Australia to implement a new national fire danger rating system, which implements a mosaic of a range of fuel categories and improved spatial risk and meteorological info. The new system has been in development for the past few years and is currently undergoing an operational trial," Peace says.

In the USA, advances in environmental system modeling components have helped the community better understand when recent impacts of warm and dry conditions have increased the threat of large wildfire development.

NOAA's Evaporative Demand Drought Index (EDDI) helps categorize recent evapotranspiration (ET) demands into a system similar to the US Drought Monitor. "Work is currently being done with various fire agencies to use the EDDI in predicting when recent high ET demand has created conditions that place further stress on local fuels, thus increasing the threat of large fires," Fontenot says.

Satellite support

Then there's the newest series of Geostationary Operational Environmental Satellites (GOES), which NOAA and NWS consider a leap forward for the operational monitoring of wildfires. "The GOES-R series of satellites can detect new wildfire starts in the western hemisphere within minutes and enable fire agencies to get automated 'hotspot notifications' of a new start," adds Fontenot.

"Once a large fire is ongoing, the data from the satellites is critical for forecast updates. The additional spectral channels available, combined with the dramatically increased temporal and spatial resolution, helps IMETs to see features that can have a substantial impact on behavior, such as small-scale atmosphere waves that can cause a wind shift or even a rapid increase in fire behavior that can lead to the development of a pyrocumlus cloud. Often fires are in areas where there's poor radar coverage, so the one-minute imagery

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HOW WILDFIRES AFFECT SNOWPACK

Wildfires have a far-reaching effect on our planet. Smoke plumes from the Australian bushfires at the beginning of 2020 were tracked around the entire southern hemisphere, with particulates recorded on glaciers in New Zealand. These fires can impact snowpack in a number of ways, including through the settling of dust, which will change the albedo of icepacks due to the darker surface, with consequent changes to melting rates.

Research undertaken by academics at Brigham Young University in Utah noted that snowpack depth was 85% greater in areas burned away by fires and that water equivalent increased in proportion to an increase in tree mortality.

Prof. Sam St Clair and his student Jordan Maxwell began studying the ecological effects of burn severity in forest systems in 2011 after the Twitchell Canyon fire in central Utah. This demonstrated a mosaic of burn severity, providing an opportunity to understand how it changed the ecology of the system. Around the same time, they received funding to look at the future of water in Utah. "And since snow in aspen forests is an important water source for Utah, we thought it would be interesting to study the effects of burn severity on the snowpack," St Clair explains.

The study found that more severe wildfire burn scars tended to accumulate more snow, which can be a positive thing if the snowpack tends to be on a more shaded aspect where the extra snow can melt more slowly. "However, it's more of a liability on sunny aspects, particularly if it results in rapid melt rates that can lead to erosion, mud slides and flooding," St Clair says. "The other potential impact is that the soot from the burned trees can collect on the snow surface, and by darkening cause more rapid snowmelt, again creating vulnerabilities and making it harder to collect that water in reservoirs."

provides IMETs with environmental intelligence that previously wasn't available."

In the UK, work is underway to redevelop the Met Office's Fire Severity Index (MOFSI) model for Scotland. MOFSI has been adapted from Canadian algorithms, and while not yet tuned to UK-specific fuel types and loads, the forecast meteorological conditions used are driven by the Met Office's numerical weather prediction model.

A consortium led by the University of Manchester has also been awarded a three-year £2m (US$2.3m) Natural Environment Research Council (NERC) grant to support its UK fire danger rating system project. "The Met Office sits on the advisory board for this project and is very keen to work with the project team on exploring how to integrate the outcomes of the project into our wildfire modeling science," notes Ian Lisk, head of hazard partnerships at the Met Office.

"In addition to short-term forecasting, research at our Hadley Centre includes longer-term projections of how fires may change in the future," adds Met Office climate scientist Chantelle Burton. "This work uses a variety of fire indices to assess the potential changes to fire weather conditions and also more complex climate models that include fuel and ignitions to assess impacts on the land and atmosphere."

Model development

In several US states, local agencies, private companies and academics are working together on ways to improve fire detection and monitoring. One interesting project comes from the University of California, where researchers have developed a machine-learning model to predict large wildfire potential from time of ignition.

There has also been significant investment in real-time cameras that provide rapid detection of new fire starts as well as fire behavior. The ALERTWildfire system, co-developed by a consortium of Californian universities, now has more than 300 wildfire-spotting cameras out in the field, having been adopted by several regional fire departments. Many of these camera sites also host automatic weather stations, according to NOAA's Fontenot. The observational data from them helps meteorologists monitor current conditions, and the data is also fed back into short-term rapid update models – such as Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR) – "thus improving mesoscale modeling", he comments.

According to Fontenot, model development continues to increase, especially in rapid update models and mesoscale modeling. He's also seeing more modeling with respect to smoke transportation and dispersion – HRRR-Smoke, for example, which is becoming more important not only for the fire weather forecaster, but also for those involved in public health as wildfire smoke becomes a bigger health issue.

"We're also seeing developments in coupled models across all the environmental spectrum, including fire behavior, so I wouldn't be surprised to see improvements in coupled meteorological-fire behavior models," Fontenot concludes. ∎

THE IMPACT WILDFIRES HAVE ON POLLUTION IN DISTANT CITIES

As we see more frequent and larger wildfires, the impact on the health of populations not directly affected is becoming an increasing concern worldwide. Wildfires are a major source of PM2.5 and PM10 particles and of trace gases, which are directly harmful to human health. Because wildfires are such a large source, the pollution travels for large distances and can affect cities many hundreds of kilometers downwind.

This was highlighted by a recent study by the University of Birmingham, UK, the Federal University of Technology, Londrina, Brazil, and the University of Stockholm, Sweden. Their work reported that wildfires, such as those that take place in Brazil, can worsen the air quality in cities up to 2,000km (1,240 miles) away.

"Our Brazilian collaborators downloaded a large amount of air-quality data from 25 monitoring sites in Paraná and São Paulo states, which they brought to us for a joint project to analyze," says Prof. Roy M Harrison from the University of Birmingham.

"Using data from across a large area allowed us to track the path of the pollution from the wildfires and evaluate the pollution load and its spatial distribution. We found substantial increases in particle and ozone concentrations to well above WHO guideline levels. This even occurred in the cities suffering an already appreciable pollution load," he notes.

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California's ALERTWildfire system now has **300+** wildfire-spotting cameras out in the field

NWS IMETs launched a sounding balloon on the Yellowstone National Park's Tatanka Complex in 2016. Photo: NOAA