THE CLIMATE LINK TO AUSTRALIA'S FIRES

Researchers race to decipher how global warming has influenced the record bush fires that have ravaged much of Australia. **By Nicky Phillips and Bianca Nogrady**

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Haze blankets Canberra on 5 January as visitors walk by Australia's parliament building.

On 1 January, the air in Canberra was the worst of any city in the world. With unprecedented bush fires raging nearby, a thick blanket of smoke smothered Australia's capital for weeks, sending a surge of residents to the hospital with breathing problems. The toxic haze got so bad that Sophie Lewis, a climate scientist at the University of New South Wales (UNSW) Canberra, took her toddler and boarded a plane to Tasmania.

"I almost wept with relief in Melbourne, on the way to Hobart, simply from seeing the sky," she says. After weeks in the smoke, her daughter had grown used to all the people walking around with "bird beaks", Lewis's name for the masks everyone was wearing.

From Hobart, Lewis fielded e-mails from concerned colleagues overseas. Like the rest of the world, they were stunned by the scale and severity of the fires ravaging Australia (see 'A country aflame'). Since September, more than 10 million hectares have burnt – an area greater than the size of Austria – and the fire season doesn't end for several months in some states. So far, the conflagrations have killed at least 32 people and destroyed more than 2,000 homes across 3 states. Through it all, people have been asking Lewis: did climate change have a role in these catastrophic fires?

Lewis and a handful of her collaborators were busy discussing that very question. They work in a small but growing field called attribution science, which calculates the likelihood that an extreme event such as a heatwave, a flood or a catastrophic bush-fire season was made worse by climate change. In a study published last December[1], Lewis and her colleagues linked catastrophic 2018 fires in northeastern Australia to climate change, and they are now planning an attribution study for the fires that have gripped large parts of the country over the past few months.

The work is being led by researchers in Europe who have conducted multiple rapid analyses of global warming's role in extreme events. The team first has to grapple with how it will define the fire event for the purpose of its study: it is tricky to model the various weather conditions that increase fire risk, and the blazes haven't yet died out. But once that is decided, the team could produce results as early as February.

Coming up with answers will be difficult. "Fire is probably the most complex physical and societal system known," says Tim Brown, a climatologist at the Desert Research Institute in Reno, Nevada. "There're so many different aspects of it, from the fuels and the people to the management practices."

But Australia and other countries need to know what they are facing. If attribution studies can quantify the role of climate change in particular extreme events, scientists can better forecast the chances that the catastrophes will strike again. Such information is vital for emergency-response managers as they prepare for a warmer Earth. Firefighters in many countries have noticed, for instance, that big blazes are getting hotter and more dangerous, so modelling studies of future risks would help them train for and respond to the conflagrations to come.

Burning lands

Australia has always had fires – catastrophic ones, too. The really devastating ones earn their own name, such as Black Friday in 1939, Ash Wednesday in 1983 and Black Saturday in 2009. The last of those killed 173 people: the continent's deadliest fire on record. All three – as well as the current crisis – happened amid or at the end of long, intense droughts.

This year's unusually hot and dry conditions are driven in part by a natural meteorological phenomenon called the Indian Ocean Dipole (IOD), which is defined by differences in sea surface temperatures across the ocean. In its positive phase, warmer waters congregate near Africa, and rainfall is reduced over the southern and most northerly regions of Australia. This year saw one of the strongest positive swings in the IOD in recent history. Coupled with these events was a shift in the polar winds above Antarctica – also a natural phenomenon, but much rarer than a positive IOD. This sudden stratospheric warming, as it is known, contributed to bringing hot, dry weather to much of Australia. On top of all this natural variation, global warming is making the country even hotter and drier, says Sarah Perkins-Kirkpatrick, a climate scientist at UNSW Sydney.

Evidence has been growing for decades that climate change will exacerbate Australia's fire seasons. A prescient paragraph in a 2008 government-commissioned climate report that compiled evidence from the previous 30 years warned that fire seasons would start earlier, end later and be more intense[2]. "This effect increases over time, but should be directly observable by 2020," noted the report, authored by Ross Garnaut, an economist at the University of Melbourne.

Lewis says we don't need attribution studies to say that climate change is generally making fires in Australia worse. But as extreme events become more frequent – and the pace of warming shows no signs of falling – people want to know whether climate change had a hand in a specific extreme event.

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Lewis's study on the 2018 event looked at 130 bush fires that razed nearly 750,000 hectares over 5 days. On one climate model, the researchers ran thousands of simulations of future conditions, and they compared a world with current greenhouse-gas concentrations against one with pre-industrial levels. Those runs suggest that climate change had made the extreme temperatures – a major driver of fire weather – 4.5 times more likely. A second model showed that the below-average rainfall was also linked to increased greenhouse-gas concentrations, but only in some climate scenarios. The researchers say the study is one of many that connect climate change to increasing fire risks in eastern Australia. The work helps to confirm what many suspect

about the impacts of the major warming in Australia, says Perkins-Kirkpatrick, one of the authors of the report. Nine of Australia's ten hottest years on record have occurred in the past 15 years.

Cause and effect

Friederike Otto, a climate modeller at the University of Oxford, UK, started contemplating an attribution study on the Australian fires after she saw satellite images peppered with conflagrations and smoke plumes stretching across the continent. The event was too big to ignore, says Otto, who is a co-investigator at World Weather Attribution (WWA), a partnership led by the university's Environmental Change Institute and the Royal Netherlands Meteorological Institute that analyses the effects of climate change on extreme weather. WWA decided to do a rapid attribution study, and invited Lewis, Perkins-Kirkpatrick and other researchers in Australia to join.

The first step in any attribution study is to set out the limits of the event (see 'A country aflame'), which is tricky in the Australian case because of the size of the area that has burnt and the time span over which it happened, says Perkins-Kirkpatrick. Once that has been done, the team will analyse whether temperature, rainfall and a 'fire-weather' index (FWI) — which includes those two variables and others — during the event were outside normal ranges. Last year was the country's driest and hottest on record, and a heatwave that affected most of the country in December smashed the record for the hottest day ever recorded in Australia. The average maximum temperature across the country reached 41.9 °C on 18 December.

To see whether climate change had a role in these extremes, the group will use half a dozen climate models to run thousands of simulations, some reflecting current greenhouse-gas concentrations and others using pre-industrial levels. The group will also determine whether climate change made fire weather worse during the event.

Perkins-Kirkpatrick is confident the study will pinpoint the influence of climate change on extreme temperatures, but its effects on dryness, humidity and winds are much harder to assess. That's why it's important to analyse the extent to which global warming influenced both the FWI and the individual components, says Otto.

The team plans to publish its results in an open-review journal, as soon as they're ready, and probably in the next couple of weeks. "For an event like this, where a lot of people have a lot of opinions on the role of climate change, it is important to make the scientific process as transparent as possible," says Otto.

The study could also feed into future attribution work on fires, for which there has been a shortage of work. Hundreds of attribution studies have shown that climate change increased the risks of specific heatwaves — including a record one in Europe last year. But only a small fraction have looked at extreme fires, partly because fires are much more complex than heatwaves or droughts, says Brown. A report examining major fires in British Columbia in Canada in 2017 found that climate change made extreme fire weather two to four times more likely and increased the area of the province that burnt by at least a factor of seven[3]. And a couple of studies have explored the factors driving a fivefold increase in the area burnt in California since the 1970s[4], and a twofold increase in burnt area in the western United States since the mid-1980s[5]. Both studies found that the particular trend was probably driven by increased drying of leaves, twigs, tree branches and other 'fuels' as a result of global warming.

Incendiary behaviour

Most fire-attribution studies have focused on answering relatively straightforward questions, such as how much climate change contributed to, or exacerbated, the event. But Brown, whose team specializes in studying fire, wants to look deeper, and investigate how climate change is altering the behaviour of fires. In particular, he and his colleagues are looking at night-time warming, a factor he thinks might link global warming to bushfire risk. When temperatures drop sharply at night, humidity tends to increase and that can help firefighters to suppress blazes. But when overnight temperatures remain high, fire managers have less success in combating fires, he says. Night-time temperatures have been climbing around much of the globe[6], and Brown is exploring whether that change is raising the risk of fires.

Scientists are also interested in examining whether fires are getting more severe. The increased fuel aridity makes fires burn hotter, which increases the chances that a blaze will create its own weather system, sparking lightning and throwing embers kilometres ahead of the fire front[7,8].

Smoke from these events can be so thick that it turns the sky an eerie red, or plunges everything into darkness. The haze travels for hundreds of kilometres, and can be seen from space. Lewis worries there isn't enough attention on the health impacts for the millions of Australians who've endured months of thick smoke. Beyond the damage to people's lungs, the fires can take a psychological toll. When residents are stuck indoors for weeks, Lewis says, the smoke "makes you feel stressed and anxious and on edge. Everything smells of smoke."

Lewis and her family stayed in Tasmania for almost two weeks. Now back in Canberra, she's seeing the effects this wild summer has had on her toddler, who has started asking where the red Sun went and what happened to all the bird-beak masks.

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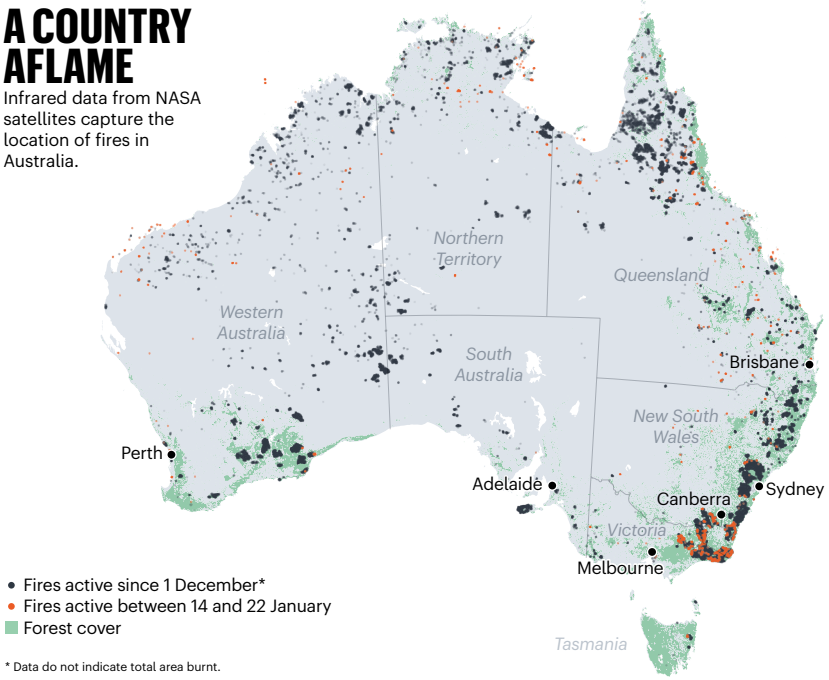
A COUNTRY AFLAME

Infrared data from NASA satellites capture the location of fires in Australia.



SOURCES: MODIS FIRE DATA COURTESY OF NASA, FIRMS; FOREST DATA FROM ESA